UNIVERSITY OF SÃO PAULO
MECHANICAL ENGINEERING DEPARTMENT

YANEY GOMEZ CORREA

A Product-Service Architecture to Design Assistive Smart Homes

São Paulo
2022

YANEY GOMEZ CORREA

A Product-Service Architecture to Design Assistive Smart Homes

Corrected Version

Master dissertation submitted to the Polytechnic School of the University of São Paulo – POLI-USP, to fulfillment of the requirements for the degree of Master in Science.

Concentration area: Control Engineering and Mechanical Automation

Corrected version containing the changes requested by the judging commission in 7 November 2022. The version The original is in a reserved collection at EM-USP Library and at Digital library USP Theses and Dissertation (BDTD), in accordance with the CoPGr Resolution 6018, of October 13, 2011.

Advisor: PhD. José Reinaldo Silva

USP – Polytechnic School
December 2022

Este exemplar foi revisado e corrigido em relação à versão original, sob responsabilidade única do autor e com a anuência de seu orientador.

São Paulo, —————— de —————— de ——————

Assinatura do autor: ————————

Assinatura do orientador: ————————

Catalogação-na-publicação

Nome: Gomez Correa, Yaney

Título: A Product-Service Architecture to Design Assistive Smart Homes

Master dissertation submitted to the Polytechnic School of the University of São Paulo –
POLI-USP, to fulfillment of the requirements for the degree of Master in Science.

Aprovado em:

Banca Examinadora

Prof. Dr. ⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯
Instituição: ⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯
Julgamento: ⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯

Prof. Dr. ⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯
Instituição: ⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯
Julgamento: ⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯

Prof. Dr. ⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯
Instituição: ⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯
Julgamento: ⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯⎯

In memory of my dad: Thank you for all love and support you gave us all ....

ACKNOWLEDGEMENTS

To Prof. Dr. José Reinaldo Silva for his timely guidance and the opportunity given...

To my mother for being the engine force behind my academic formation, the one who guided my steps when the lights went out...

To all my family for being beside me when I need it...

To my little champion ... God take care and protect you always...

To Yanela, thank you for being part of this dream ...

For all my friends with whom I have shared laughter and tears ...

To Margarita, thanks for your unconditional friendship....

To my colleagues at D-Lab for their time and precise help.

To the Mechanical Engineering Department of the Polytechnic School of São Paulo University for all support provided during this time.

A man is but the product of his thoughts, what he thinks, he becomes.
— *Mahatma Gandhi*

ABSTRACT

CORREA, YANEY GOMEZ. **A Product-Service Architecture to Design Assistive Smart Homes**. 2022. 159 f. Master dissertation (Master student em in Science. Area: Control Engineering and Mechanical Automation) – Escola Politécnica (POLI/USP), São Paulo.

The world of home automation and the smart home is changing. Population aging, chronic diseases increase and the cost of health services increases meaning that houses are considered a possible alternative to replacing (at least partially) hospitals and health institutions. Smart homes offer facilities and features that improve the quality of life for patients, the elderly, and people who need health assistance. Today, the technological solutions available are no longer just synonymous with comfort and safety, expanding the scope to include solutions for health systems.

Smart home technology is an emerging field of automation that integrates different areas, including electrical, mechanical, and hydraulic automation subsystems and sensors associated with sophisticated monitoring and control. Recently, these systems have also received missions to assist specific users, such as the elderly or patients who need intensive care, introducing the direction to Service Engineering. This challenge puts enormous pressure on the development of engineering requirements that correspond to the automation goals raised by telemedicine, treating these smart homes as a System of Systems (SoS) with a global goal (social goal) that combines comfort, safety, and flexibility with healthcare, protection, and telemedicine.

The proposal presented is based on a multilayer[1] approach where all the services involved can be modeled and matched, respecting the limits of their specifications, in a single system that achieves the proposed objective. Intelligent systems in these layers justify the use of Artificial Intelligence (AI) planning, in which automated processes achieve the objectives of each service. This substantially changes home automation projects, which should be designed to be reused, and creates a link with health and telemedicine.

The work focus is on goal-oriented requirements modeling (Goal Oriented Requirements Engineering) which specifies processes subsequently transferred to Petri nets.

Key-words: Goal-oriented requirements engineering, service architecture, healthcare, home automation, smart home.

---

[1] A layer is assigned to each service involved in the modeled system. For an Assistive Healthcare System, different services can be involved (Hospitals, clinics, laboratories, pharmacies, home automation, automated houses, or apartments) already implemented and that must be coupled.

RESUMO

CORREA, YANEY GOMEZ. **A Product-Service Architecture to Design Assistive Smart Homes**. 2022. 159 f. Master dissertation (Master student em in Science. Area: Control Engineering and Mechanical Automation) – Escola Politécnica (POLI/USP), São Paulo.

O mundo da automação residencial e da casa inteligente está mudando. O envelhecimento populacional, as doenças crônicas aumentam e o custo dos serviços de saúde aumenta, fazendo com que as casas sejam consideradas uma possível alternativa para substituir (pelo menos parcialmente) hospitais e instituições de saúde. As casas inteligentes oferecem facilidades e recursos que melhoram a qualidade de vida de pacientes, idosos e pessoas que precisam de assistência médica. Hoje, as soluções tecnológicas disponíveis deixaram de ser apenas sinônimo de conforto e segurança, ampliando o escopo para incluir soluções para sistemas de saúde.

A tecnologia de casa inteligente é um campo emergente de automação que integra diferentes áreas, incluindo subsistemas de automação elétrica, mecânica e hidráulica e sensores associados a monitoramento e controle sofisticados. Recentemente, esses sistemas também receberam missões para atender usuários específicos, como idosos ou pacientes que necessitam de cuidados intensivos, apresentando a direção para a Engenharia de Serviços. Este desafio pressiona enormemente o desenvolvimento de requisitos de engenharia que correspondam aos objetivos de automação levantados pela telemedicina, tratando essas casas inteligentes como um Sistema de Sistemas (SoS) com um objetivo global (objetivo social) que combina conforto, segurança e flexibilidade com saúde, proteção e telemedicina.

A proposta apresentada é baseada em uma abordagem multicamada[2] onde todos os serviços envolvidos podem ser modelados e compatibilizados, respeitando os limites de suas próprias especificações, em um único sistema que atinja o objetivo proposto. Sistemas inteligentes nessas camadas justificam o uso do planejamento de Inteligência Artificial (IA), em que processos automatizados atingem os objetivos de cada serviço. Isso altera substancialmente os projetos de automação residencial, que deveriam ser projetados para serem reaproveitados, e cria um vínculo com a saúde e a telemedicina. O foco do trabalho é a modelagem de requisitos orientada a objetivos (Engenharia de Requisitos Orientada a Objetivos) que especifica processos posteriormente transferidos para redes de Petri.

Palavras-chave: Engenharia de requisitos orientada a objetivos, arquitetura de serviço, serviço de saúde, automação residencial, casa conectada.

---

[2] Uma camada é atribuída a cada serviço envolvido no sistema modelado. Para um Sistema Assistivo de Saúde podem estar envolvidos diversos serviços (Hospitais, clínicas, laboratórios, farmácias, domótica, casas automatizadas ou apartamentos) já implementados e que devem ser acoplados.

LIST OF FIGURES

LIST OF TABLES

LIST OF ABBREVIATIONS AND ACRONYMS

AI .... Artificial Intelligence
CPAP .... Continuous Positive Airway Pressure
D-Lab .... Design Lab
DTD ..... Document Type Definition
GORE ... Goal-Oriented Requirements Engineering
HPN ..... Hierarchical Petri Nets
HTML ... HyperText Markup Language
IDE ...... Integrated Development Environment
JAD ...... Joint Application Development
JSON .... JavaScript Object Notation
KAOS ... Knowledge Acquisition in autOmated Specification
KML ..... KAOS Markup language
LTL ...... Linear Temporal Logic
MBRE ... Model-Based Requirements Engineering
PN .... Petri net
PNML ... Petri Net Markup Language
PSA ..... Product-Service Architecture
RAD ..... Rapid Application Development
RE .... Requirements Engineering
RFID ..... Radio Frequency Identification
SoS ...... System of Systems
UML ..... Unified Modeling Language
W3C ..... World Wide Web Consortium
XHTML . EXtensible HyperText Markup Language
XML ..... eXtensible Markup Language
XSD ..... XML Schema Definition
XSLT .... eXtensible Stylesheet Language

CONTENTS

CHAPTER

1

INTRODUCTION

After a period of a great rise in the 1990s, building and residential automation went through several challenges (SILVA, 2003):

1. regarding design methods and their adaptation to methods already in use;

2. treating legacy systems and demands to automate buildings and residences already planned and even built;

3. to use the equipment inherited or adapted from industrial automation;

4. guarantees a return on investment in projects linked to comfort and, in some cases, to safety, reducing the target users.

The evolution of the market had a good phase - with the growth in the number of new approaches for home automation and the appearance of standards and new specialized equipment. However, design methods still did not include user interactions explicitly. In this century, especially in the last ten years, building and residential automation returned to the scene, whether from an academic point of view - with the perspective of innovation in design methods and equipment - or from a market point of view, with new perspectives of incorporating buildings in the basic project and not only as comfort options. In particular, the possibility of using digital convergence (NOF; SILVA, 2018) to implement a modern version of home care [3].

A discussion started at the beginning of this century involving academics and practitioners about the role of home automation. A group advocated that home automation is the provision of services, as it has happened since the last century. The prospect for the future would be the sophistication of these services. Another group says that it is not

---

[3] The first initiatives in-home care date from the first decade of the 20th century with visiting nurses in the United States.

just a question of sophisticated services, usually treated as superfluous items, but of diversifying and democratizing the use of automated items. According to this group, home automation issues would integrate naturally with other services in the scope of general projects, such as the provision of water, energy, security, or air conditioning (as a service clustered architecture and no longer as a client architecture). In both cases, especially in the second, the prospect is for a major expansion in the design methods of intelligent systems and residential automated services. This proposition expands the degree of engagement between the residence and its users and proposes diversifying and refining design methods, especially in the requirements phase (CHIABRANDO *et al.*, 2018).

Besides, the aging of the world population, increased chronic diseases, inaccessibility, and increased health services costs. Therefore, private homes must be considered a possible replacement for hospitals and healthcare institutions. This alternative can also reduce costs and internment time for those recovering from surgical procedures or supply automated monitoring for older adults. Thus, smart homes must provide facilities and functionalities that improve patients' quality of life, both for the elderly and convalescent people (ALAM; REAZ; ALI, 2012), (BDIC; BREZOVAN; BDIC, 2013), (CHAN *et al.*, 2008), (WILSON; HARGREAVES; HAUXWELL-BALDWIN, 2015): An even greater demand is created for vulnerable patients, elderly or convalescent, especially in BRICS countries, where it depends on public health services.

Thus, smart home technology is a promising field of automation that matches and integrates sophisticated equipment with diverse measurement and control techniques. Smart homes need security monitoring, remote control of domestic tasks, sound and lighting control, energy management, well-being, harmonizing technologies with user needs, respecting cultural issues, sustainability, and the capacity to regenerate the environment and resources (MARTINS; ALMEIDA; CALILI, 2017). However, to achieve its main social goal, residential automation systems must match requirements defined by intelligent computational software directly concerned with integrating the system with end-users.

This work proposes a multilayer architecture for healthcare services, matching processes in health services to basic automated systems, reinforcing a service design approach. Therefore, home automation issues link with health and telemedicine and healthcare services. The matching is performed during requirements modeling, which points to an approach goal-oriented instead of functional, formalized in Petri Nets.

1.1   The research problem

Many researchers and system developers have discussed formal methods to represent requirements. Typically, they have an informal representation of needs from

stakeholders interacting with one system as their starting point. Therefore, one of the main challenges is to express the system's needs, properties, and characteristics by requiments schemas and transform them into formal representations to analyze, verify, and validate the initial models.

Homecare services require a different approach compared to the traditional healthcare system. Population aging reinforces the necessity to use resources and medical assistance without leaving home. This demand grows in quantity and by diversifying pathologies, and medical treatments (DAIMI *et al.*, 2010). On the other hand, homecare resources are limited, and healthcare providers face significant challenges in designing and operating efficient healthcare systems. In this context, homecare systems appear as alternatives to improve the health services' performance (GUTIERREZ; GUTIERREZ; VIDAL, 2013).

The main problem is to propose an architecture to enable matching requirements from home automation and a healthcare service layer and its coupling with the end user.

1.2 Objectives

The general objective of this work is to propose a model for a two-layer design architecture, integrating physical home automation and the service system directed to intensive care processes, privileging the coupling with the end user. The specific objectives are:

- To insert the layered requirements modeling in the Model-Based Requirements Engineering (MBRE) method proposed by Design Lab (D-Lab).

- To create a method and algorithm for transferring semiformal Knowledge Acquisition in autOmated Specification (KAOS), used to model objective-oriented requirements, to Petri nets.

- To develop a formal matching process between the Petri nets of the assistive service system and the residential automation base, supporting the analysis and verification of requirements.

1.3 Contributions

The present work uses the possibilities offered by the method framed in the requirements engineering process to design domotic healthcare systems.

Another contribution is the multilayer architecture for designing intensive healthcare systems over legacy residential automated houses. The proposed method allows consistency and integration of service-oriented health systems without redundancies,

replication of supplies and equipment, and the reuse of home automation systems already implement.

1.4   Methodology

The methodology used in this research is theoretical documentary, which includes reviewing different models present by recent scientific literature, applying a systemic approaches to the represent models for analyzing and verifying systems.

A sound bibliographic research covers the current scenario regarding methods, architectures, and models of smart homes, focusing on healthcare services available in databases of scientific production, to show the pertinence of the proposal.

For the development of the work and reaching the objectives proposed, it was carried out a study on the main concepts of Requirements Engineering, Model-Based Requirements Engineering, PSA (Product-Service Architecture), and the study of Modeling and Design validated by Petri nets.The steps of the method applied in this work are:

1. To develop theoretical aspects of the design of domotic Systems coupled with healthcare services, using requirements engineering concepts based on objectives, and exploring Product-Service Architecture (PSA).

2. Contribute to exporting documented requirements in eXtensible Markup Language (XML) files that can be transferred into Petri Net Markup Language (PNML) and Petri Nets.

3. Integration of the previous techniques to compose a closed design method for matching an assistive service system and an existing residential automation model.

4. Application in a case study.

1.5   Work Organization

The content of the present work is organized as follows:

- Chapter 2: presents the literature review evidencing needs and research opportunities. Introduce background topics such as Requirements Engineering, Goal-Oriented Requirements Engineering (GORE) methodology, KAOS method, Petri net Modeling, Goal-Oriented requirements for telemedicine, Healthcare service in Smart Home, and the Product-Service Architecture (PSA).

- Chapter 3: presents a multilayered approach for the service design proposed in this work.

- Chapter 4: presents a case study for a healthcare service.

- Chapter 5: presents the conclusions and further work followed by the bibliographic references consulted.

CHAPTER

2

BACKGROUND AND MOTIVATION

This chapter presents an approach to Requirements Engineering that fits the goal-oriented method into systems design. The proposal is applied to model healthcare services implemented in smart homes. The chapter starts with some basic concepts of the GORE method, represented by KAOS diagrams. A summary of smart home designs implemented by the academy and in the market, focusing on services. The Petri net formalism is introduced for the formal analysis and modeling of requirements, connecting the present work with the concept of PSA (Product-Service Architecture).

2.1 Requirements Engineering

Requirements Engineering (RE) (Figure 1), is a discipline that aims to ensure that desired needs of stakeholders - including final users - could be satisfied. Its principal activities can be enumerated as:

- A requirements elicitation phase that aims to discover the stakeholder's needs and user expectations and understand the context in which the system-to-be will operate. Distinct techniques could be used: (i) traditional data gathering techniques (e.g., interviews, questionnaires, surveys, analysis of existing documentation), (ii) collaborative techniques (e.g., brainstorming, Rapid Application Development (RAD)/Joint Application Development (JAD) workshops, prototyping), (iii) cognitive techniques (e.g., protocol analysis, card sorting, laddering), (iv) contextual techniques (e.g., ethnographic techniques, discourse analysis), and (v) creativity techniques (e.g., creativity workshops, facilitated analogical reasoning)(BENNACEUR *et al.*, 2019).

- A Modelling and Analysis phase, which follows the elicitation activity, demanding a more precise description. Many techniques and notations can also be used for

this phase, ranging from informal to semi-formal visual approaches to formal methods. The choice of the appropriate method often depends on the kind of analysis or reasoning needed (BENNACEUR *et al.*, 2019).

- Requirements quality assurance seeks to identify, report, analyze and fix defects in requirements. It involves both validation and verification. Validation implies checking the adequacy of the specified and modeled requirements and their domain assumptions with the actual expectations of stakeholders. Verification covers many approaches, implying quality criteria for specified and modeled requirements demanding formal representations. (BENNACEUR *et al.*, 2019).

- Requirements management is an umbrella term for handling changing requirements, reviewing and negotiating their scope and priorities, and maintaining traceability between requirements and artifacts (BENNACEUR *et al.*, 2019).
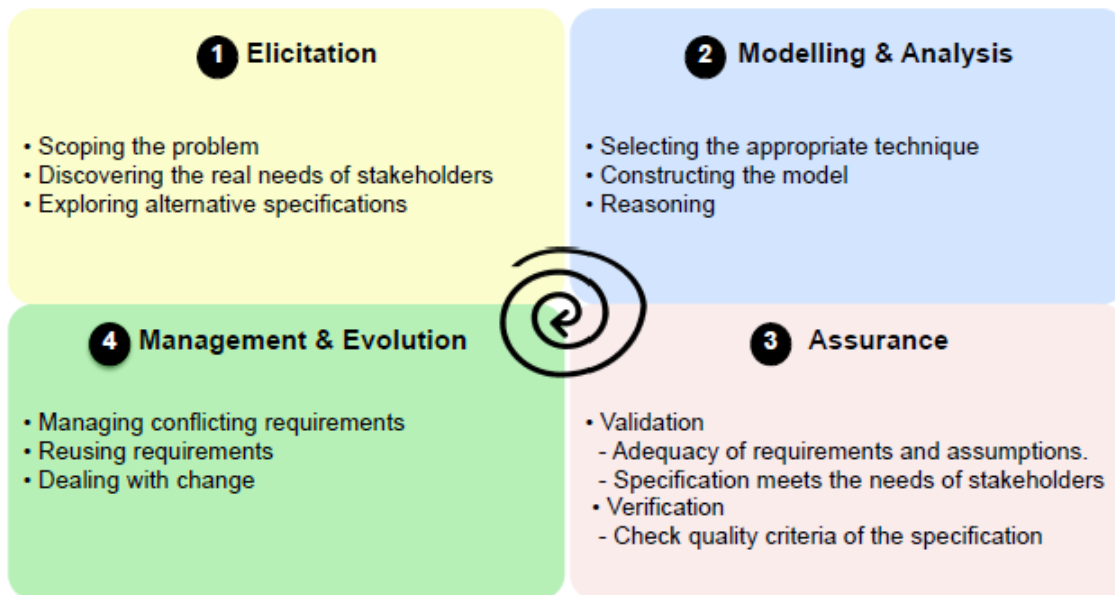
Figure 1 – Main activities of Requirements Engineering. Source: (BENNACEUR *et al.*, 2019).

Requirements can be classified as:

- Functional requirements: Describing input/output transformations represented as functions mapping a domain to a co-domain. From a General Systems Theory perspective, engineered systems are necessarily open, mapping the transformation of an input into a different output.

- Performance requirements: Defining the necessary characteristics, properties, or attributes associated with the inputs and outputs of the system's transformations.

Indeed, this condition is necessary because any attribute transparent to the interaction between the system and its external context should not be considered a requirement and should not constrain the solution space.

- Resource requirements: Defining limits on resources consumed by the system. Resources must therefore be inputted into the system and consumed to produce something. Hence, any limitation on resource consumption is part of a functional exchange and can be modeled accordingly.

- System environment: an abstraction for all elements composing the system external context. The environment provides certain conditions under which the system must operate and imposes certain limitations on how it may affect the environment. In other words, the environment provides specific inputs under which the system must operate and imposes certain limitations on the outputs the system may yield. An appropriate RE process can ensure correct definitions in the domain description and the problem to be solved; in addition, the requirements must meet quality conditions such as:

    - Measurability: If a system solution is proposed, one must be able to demonstrate that it meets its requirements. Agreement on such measures will then reduce the potential dispute with stakeholders.

    - Completeness: Requirements must define all properties and constraints of the system-to-be. Completeness is achieved by defining requirements statements, such as ensuring that there are no missing references, definitions, or functions.

    - Correctness (sometimes also referred to as adequacy or validity): The stakeholders and requirements engineers have the same understanding of what is meant by the requirements. Practically, correctness often involves compliance with other business documents, policies, and laws.

    - Consistency: Multiple stakeholders hold different views of the problems to be addressed, which might be contradictory at the early stages. Negotiating conflicts between these requirements must converge to an agreement.

    - Unambiguity: The terms used within the requirement statements must mean the same to those who created and used them.

    - Pertinence: Clearly defining the scope of the problem to solve. Requirements must be relevant to the needs of stakeholders without unnecessarily restricting the developer.

    - Feasibility: Requirements should be specified so that they can be implemented using the available resources.

    - Traceability: When requirements change or evolve, traceability can help to identify the impact and assess how the change should be propagated.

Figure 1 depicts a Model-Based Requirements Engineering:
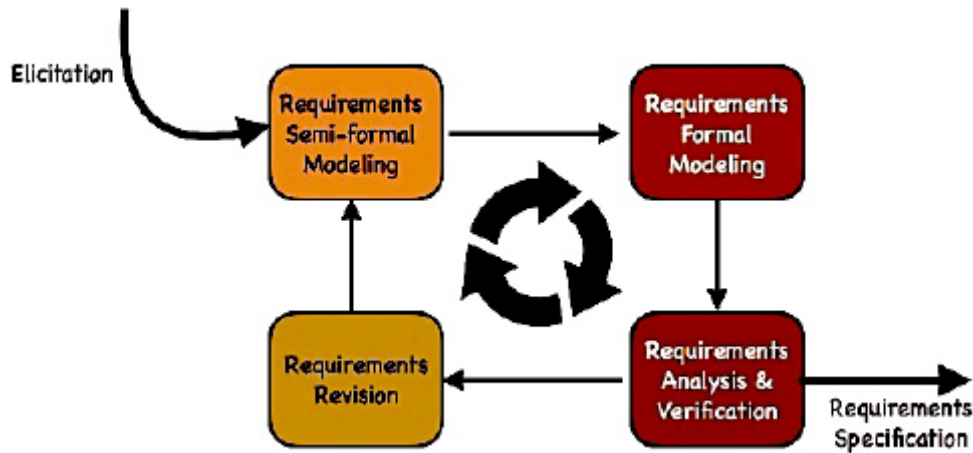
Figure 2 – Model-Based Requirements Engineering Cycle. Source: (SILVA *et al.*, 2021).

Figure 2 shows D-Lab cycle proposal, assuming that KAOS representation is used to requirements modeling, formalized in Petri Nets. This proposal also assumes that it is possible to detach invariant requirements.

At each "step" (a complete modeling cycle), a consistent model emerges, though abstract, reflecting the basic requirements or *invariant requirements* for the entire process. The analysis performed at the end of each cycle is based on the compliance with these invariant requirements and on the consistency of the current model. Therefore, a consistent partial model fully conservatively satisfies the invariant requirements. The refinement should then lead to a final model that fully satisfies (correctly and completely) all requirements. The requirements cycle is iterative and convergent. The formal modeling is concerned explicitly with verification - preserving invariants and the scope of requirements - and convergence (SILVA *et al.*, 2021).

2.1.1   GORE methodology

(HORKOFF *et al.*, 2016) defines the Goal-Oriented Requirements Engineering as the study or application of goal models in Requirements Engineering. A goal model is a model expressed in a goal-oriented language. Such languages include the concept of goal as a first class object, are often graphical, and come with a visual syntax.
The GORE methodology approaches RE from a goal-oriented perspective using various methods for this purpose. Objectives are usually conceptualized in some type of model, and have been applied more broadly to advance the state of software adaptation, security, legal compliance, and business intelligence, among other areas (HORKOFF *et al.*, 2019).
A goal is an objective that the system under consideration should achieve. Objectives can be formulated at different levels of abstraction, ranging from high-level strategic

concerns to low-level technical concerns. The objectives also cover different types of concerns: functional concerns associated with the services to be provided and nonfunctional concerns associated with the quality of service, such as safety, security, accuracy, performance, etc (Van Lamsweerde, 2001).

According to (Van Lamsweerde, 2001), the importance of goals in the RE process is given by:

- Achieving requirements completeness is a major RE concern. Goals provide a precise criterion for sufficient completeness of a requirement specification.

- Avoiding irrelevant requirements is another major RE concern. Goals provide a precise criterion for requirements pertinence.

- Explaining requirements to stakeholders is another important issue. Goals provide the rationale for requirements and are closer to the goal registered in project documentation.

- Goal refinement provides a natural mechanism for structuring complex requirements documents for increased readability.

- Requirements engineers are faced with many alternatives to be considered during the requirements elaboration process.

- Managing conflicts among multiple viewpoints is another major RE concern.

- Separating stable from more volatile information is another important concern for managing requirements evolution. A requirement represents one particular way of achieving some specific goal; the requirement is therefore more likely to evolve towards another way of achieving that same goal, than the goal itself.

- Goals drive the identification of requirements to support them; they have been shown to be among the basic driving forces, together with scenarios, for a systematic requirements elaboration process.

2.1.2   *KAOS diagrammatic modeling*

KAOS (Knowledge Acquisition in autOmated Specification) is a semiformal and diagrammatic goal-based requirement engineering method. KAOS's specificity is that it can implement goal-based reasoning. A goal defines an objective the system should meet, usually through the cooperation of multiple agents such as devices or humans. A goal (objective) model starts decomposing goals and subgoals until it reaches a requirement or expectation. Software agents are responsible for these requirements

or expectations. A transactional interface expresses the human agent's relationship with the system. This model is top-down - especially for systems - beginning with the most abstract goal and refining it with sub-goals (WERNECK; De Padua Albuquerque Oliveira; Do Prado Leite, 2009). KAOS differentiates between goals and domain properties, that is, descriptive statements about the surrounding environment such as physical laws, organizational norms or policies, and others. KAOS, Figure 3, is composed of several sub-models related through inter-model consistency rules:

- The goal model contains all the goals of a system and its relationship with the environment. Goals are organized in a hierarchy obtained from refining higher-level goals (the system goal) into lower-level ones using refinement patterns. Higher-level goals are strategic and coarse-grained, while lower-level goals are technical and fine-grained (more operational).

- The object model defines the agents (humans and machines), active or passive, that contribute to the system's functioning.

- Agent's responsibility mode assigns goals to agents, allowing impact analysis and proper negotiation in case of changes.

- The operation model sums up all the behaviors agents needs to have to satisfy requirements. Those operations work on the objects described in the object model. They can create objects, provoke state transitions, or trigger other operations by sending and receiving events or messages (MATOUSSI; PETIT, 2009).

The KAOS concepts of obstruction, obstacles, refining, and resolution allow for defining failure or crash scenarios for the goals and the associated risks. KAOS provides a detailed basis for the description of tasks (actions), see that an action is related to a constraint and to an object, which can be: an agent, an event, an entity, or a relation. It also provides a more explicit mechanism to address risk analysis, with the concept of obstacle (restriction) (WERNECK; De Padua Albuquerque Oliveira; Do Prado Leite, 2009). The KAOS graphic elements shown in Figure 3 are defined below:

- Objectives: An statement expressed by stakeholders describing the objective/goal for which the system or sub-system is designed.

- Requirements: It is a low-level objective/goal type with clear criteria for user satisfaction.

- Obstacle: It is an event or restriction unfavorable to the satisfaction of the system's objectives/goals.
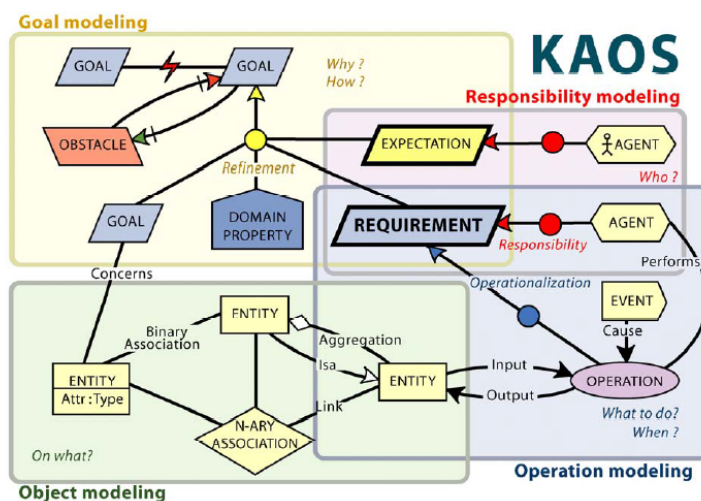
Figure 3 – KAOS models. Source: (RESPECT, 2007).

- Agents: All those active physical objects (system agents), such as humans (for example, suppliers), or logical objects (software agents), such as machines (for example, routers), responsible for carrying out requirements and expectations.

- Entity: Represent passive and independent objects. Passivity means that they cannot carry out operations, and independence means that their descriptions do not depend on other objects.

- Domain-property: Description of the context or environment subject to change. It can be a domain invariant or a domain hypothesis. The domain invariant is a domain property that must be true in all system states. The domain hypothesis is a type of property expected to be true to satisfy an objective/ goal.

- Expectation: There are no clear criteria for its satisfaction. If requirements are assigned to a software agent, expectations are just checked by a system agent.

- Refinement (yellow link): It connects an objective/goal to other subgoals/subgoals. Each connection contributes to the satisfaction of the objective/goal being refined.

- Conflict: It is used to designate the existence of an object's component that prevents another goal satisfaction.

- Assignment (pink link): Used to assign the agent responsible for satisfying requirements, expectations, or objectives/targets.

- Responsibility (red link): Used to connect the agent responsible for direct satisfying requirements or expectations.

- Operationalization (blue link): Used to connect operations with requirements or expectations.

2.2   Petri nets

The Petri net (PN) formalism was created in 1962 as part of Carl Adam Petri's doctoral thesis, presented at Darmstadt University of Technology. The initial goal was to provide a clear and concise representation of inter-process communication in automated systems.

The PN is a formalism for modeling, analyzing, and verifying discrete systems. Formal analysis can reveal necessary information about the structure and dynamic behavior of the modeled system and is applied to validate requirements satisfaction or to evaluate improvements or changes.

Applications areas are: conceptual modeling and analysis of dynamic systems, distributed data on financial systems, concurrent programming and parallelism, flexible manufacturing control, discrete event systems, computer networks, data-flow, fault-tolerant systems, asynchronous circuits, compilers, and operational systems, formal languages and logic programs (Murata, 1989).

Indeed, Petri net is a generic term used to designate a family of related discrete event formalisms sharing some basic relevant features such as a minimalist number of primitives, non-determinism, locality of the states, and actions (with consequences over the model building and structuring) or real-time. A system's global state is a set of independent local states. The occurrence or firing of a transition captures the basic notion of the model's behavior by its effect on the local states. A PN model can capture other notions of system behavior when occurrences of sets of transitions are considered, expressing concurrency, synchronization, choice, or total ordering. Local state variables (places), state transformers (transitions), and the declared relations between them define the structure of the Petri net model. The value of a local state variable is called its marking. The global state or marking of the system is the concatenation of the marking of the different places (SILVA, 2013).

In particular, a PN (Figure 4) has two types of nodes: conventionally, the circles represent places, and the bars (or rectangles) represent transitions. In this way, we can say that a PN is a relational representation composed of places (P) and transitions (T). Formally, we denote it as a bipartite graph $G = (P,T)$, where $V = P \cup T$ and $P \cap T = \phi$.

Guided arches connect places and transitions: some arcs are oriented from place to
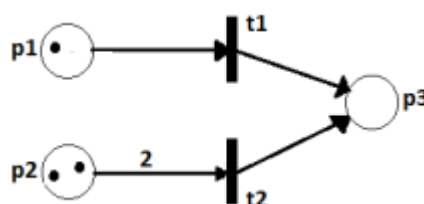
Figure 4 – A simple example of a Petri net graph.

transition, and others from transition to place. An arc directed from a place P_j to a transition T_j defines the place as a pre-condition to that transition. When multiple arcs enter a transition, this transition is said to have multiple inputs or pre-conditions, expressed by the input function $I(T_j)$. Similarly, arcs that start from a transition T_j point to places that constitute the exit of that transition and are represented by the function $O(T_j)$. According to (Murata, 1989), a Petri net is formally defined as a 5-tuple $PN = (P; T; F; W; M_0)$ where:

- $P = \{p_1, p_2, p_3, ...p_m\}$ is the finite set of places;

- $T = \{t_1, t_2, t_3, ...t_m\}$ is the finite set of transitions;

- $F \subseteq (PXT) \cup (TXP)$ is the set of arcs (flow relation);

- $W : F \rightarrow 1, 2, 3, ...$ is the weight function;

- $M_0 : P \rightarrow 0, 1, 2, 3, ...$ is the initial mark of the network.

The appealing characteristics of Petri nets include: (1) the ability to represent concurrency, causality, synchronizations, resource sharing, conflicts, bulk or lot-based services and arrivals, in a natural way; (2) a formal graphic representation, which facilitates their use as a means of communication; (3) a clear representation of the paradigm state-transition by locality of states and actions that leads to distributed and structured state representations; (4) adequacy for representing essential features using the appropriate abstraction level; (5) schematic interpretability, providing the possibility to associate graphs to a wide range of meanings connected to different applications; (6) formal/precise semantics, which allows the undertaking of rigorous analysis of control automation; and (7) an easy translation of the formal model to executable code, allowing simulation, rapid prototyping, and detailed code generation (eventually becoming fault-tolerant) (SILVA, 2013).

2.2.1 Functional properties

Depending on initial marking (Murata, 1989), some behavioral properties are:

- Reachability: Marking M_n is achievable if there is a sequence of triggers leading from M_0 to M_n. Reachability is a fundamental property for the dynamic analysis of any system.

- Limitation: A PN is limited or k-limited if the number of marks in each place does not exceed a finite number k for any mark reachable from M_0, that is, that $M(p) \leq k$ for every place p. If the PN is 1-limited, then the network is called secure.

- Liveness: Is related to the absence of deadlocks. Thus, a PN is called live if every marking reachable from M_0 enables at least one transition. Liveness is considered a desirable property for any system; however, directly verifying its reverse - deadlock - can be combinatorially explosive.

- Reversibility: A PN is reversible if, for each marking $MinR(M0)$, M_0 is reachable from M.

- Persistence: A PN is persistent if, for any pair of transitions, triggering one of them does not disable the other. Every network is considered persistent if, every time a transition is enabled, it remains enabled until triggered. Persistence is a property that is related to conflict-free networks.

2.2.2 Structural properties

Structural properties do not depend on the initial marking but the structure of the network (Murata, 1989):

- Structural Limitation: A PN is structurally limited if it is limited to any finite initial mark M_0, that means if there is an m-vector x of positive integers such that: $A^T x \leq 0$, A is the incidence matrix;

- Conservative: A PN is conservative if there is a mark weight vector x, where x(p) is a positive integer for every place p. That is, if and only if there is an m-vector x of positive integers such that: $A^T x = 0$, A is the incidence matrix, and $x \neq 0$;

- Repeatability: A PN is repetitive if there is a marking M_n and a firing sequence s from M_0 so that each transition happens infinite times in s;

- Consistency: A PN is considered consistent if there is an M_0 mark and a firing sequence s from M_0 to M_d, such that each transition happens at least once in s;

- Structural Liveliness: A PN is structurally alive if there is an initial live mark for the network;

- Invariants: Represent the conservative and repetitive components of the network. There are two invariants: place invariants (representing the conservative components) and transition invariants (representing the repetitive components).

2.3 Goal-oriented requirements for telemedicine

Telemedicine is closely connected to remote healthcare systems. It was proposed almost 30 years ago to provide affordable medical services for places with insufficient

health infrastructure. Indeed, physicians can interact with patients located in remote and rural areas using information technology, and telecommunications (PRAMANIK; PAREEK; NAYYAR, 2019).

Telemedicine is based on systems that require data from equipment, software, and web applications, provided by local/remote clinics or medical centers and transmitted to specialized doctors and care centers connected to different hospitals (PRAMANIK; PAREEK; NAYYAR, 2019). Among the main activities related to telemedicine telemetry, teleconsultation relates to medical recommendations and telemonitoring. Teleinterconsultation enables the exchange of information between doctors and health agencies. Therefore, a complete telemedicine environment is a service system and deserves a service design approach.

As in any other area of engineering, telemedicine systems must emerge from a process of model-based requirements engineering (SILVA *et al.*, 2021), as proposed in the next chapter. The increasing demand forces enormous growth and interest in home health care systems to fit the need to reduce the pressure on the hospitals. Technological advances in computing, networking, medical devices, sensors, and the pharmaceutical industry has their tangible impact on improving the home health care processes (DAIMI *et al.*, 2010).

There is a continuing need for well-designed, acceptable Home Care Systems. However, the requirements complexity of individuals and the network of contributing subsystems surrounding people in their homes makes providing home care solutions difficult. Each person involved in the system and its development is likely to have very different needs, perspectives, and accountabilities, possibly changing over time as the person's condition and the system's possible behaviors change (MCGEE-LENNON; GRAY, 2007).

The domain of action of home care is the set of services directly connected to healthcare or not that function to offer assistance to the user or patient at home, taking into account a series of needs of various stakeholders categorized according to (MCGEE-LENNON; GRAY, 2007) in the cared, the carer(s), the visitors, the remote users, the technology provider(s), the institutional stakeholders and other stakeholders (this might include members of the family and neighbors who are worried about the potential effect of "special" technology on their own home.)

(MCGEE-LENNON; GRAY, 2007) distinguish between:

• The social and professional aspects of home care, including the people being cared for, the carers, and any external stakeholders playing a role in the care taking, their respective roles and interactions with one another, which we call the 'Homecare Network'.

• The technology used to support and realize activities of the Homecare Network, providing the means to collect, distribute, analyze and manage related information. Such technology typically includes sensors, devices, displays, data, networks, and computing infrastructures.

Home care systems have multiple users, multitask, and contain multiple collaborative and distributive stakeholders such as doctors, hospitals, caregivers, nurses, insurance companies, home care agencies, and pharmacies; all influencing system's behavior and functionality (DAIMI *et al.*, 2010). Home care systems tend to have dynamic needs due to the variety of services distributed by devices, which allow the user to choose different modalities for a particular task.

Many viewpoints call for a set of requirements the system must meet to deliver a final service. The dynamic relationships generated significant changes in the system's behavior, which becomes a challenge to model and design homecare systems. The requirements raised evolve and change during elicitation, negotiation, and modeling due to changes in the viewpoints. Therefore, the home care system requirements must be adapted during the modeling to achieve the established goal.

Some examples of requirements affected by changing viewpoints are:

- Functional requirements concerning the doctor and his interaction with the user, which involve measures and information taken by the doctor and communicated to the patient; patient monitoring through medical equipment sensors;

- data uploads to hospital records (electronic medical records);

- communication with the entities responsible for paying home care services (insurance, company, government).

Regarding non-functional requirements, we have as general examples performance requirements, usability, security, privacy, maintenance, and reliability (MCGEE-LENNON, 2008).

The Goal-oriented approach (GORE) is suitable for modeling and analyzing requirements of healthcare systems because it delays a separated definition between functional and non-functional requirements and presupposes a formal representation. Consequently, this approach is reliable in reinforcing the developed system's integrity, correctness, relevance, consistency, traceability, and uniqueness. All that features are crucial for automation, and particularly for healthcare automation.

The basic concepts of GORE are in Appendix A, based on its practical implementation (used in this work) in KAOS diagrams, which can be used as an alternative to schematic modeling usually done in Unified Modeling Language (UML). Practical use was directed to a software tool called ObjectivER, which formalizes requirements in Linear Temporal Logic (LTL). However, our focus is on workflow and automated systems. Thus, this work participated in a global research work of D-Lab to synthesize a KAOS Markup language (KML) to capture the requirements diagrams and translate it

to a formal model in Petri nets (PN) place/transition (P/T). Formal verification will be performed in PN.

2.4 Healthcare services in Smart Home

Telemedicine is closely connected to remote healthcare and indirectly with home care. It appeared almost 30 years ago to provide affordable medical services for places with insufficient health infrastructure. Indeed, physicians can interact with patients located in remote and rural areas using information technology and telecommunications (PRAMANIK; PAREEK; NAYYAR, 2019). In the last decade, smart homes have become possible replacements for hospitals and health institutions. The aging of the world population, the increase in chronic diseases, inaccessibility, and the increase in the demand for costs of health services are pressuring public services, preventing their rational use.

Smart homes are alternatives to reduce costs and hospitalization time for those recovering from surgical procedures and provide automated preventive monitoring for older adults and those who need it.

New functionalities are being incorporated into smart homes to improve the users' quality of life, starting by incorporating home automation services integrated with home care services. We enumerate some essential issues required from home automation to support healthcare systems:

- Comfort: providing automated environments and equipment to enable tasks' programming and remote activation. Technological advances in home automation are achieved by using sensors and actuators, communication protocols through platforms on the internet, and intelligent interfaces activated by voice or gestures - essential to intensive home care (ALAM; REAZ; ALI, 2012), (CHAN *et al.*, 2008).

- Security: requiring user authentication, antivirus protection, encrypted data, video surveillance, remote monitoring, alarm, and emergency response to the user. The main reason is to detect abnormal situations inside the house: fire, floods, falls of disabled or old adults, and the detection of invasion (WILSON; HARGREAVES; HAUXWELL-BALDWIN, 2015).

- Energy management and sustainable use of natural resources: usually, modern houses depend just on electricity, and energy expenditure increases with the use of computers, smartphones, appliances, air conditioners, and medical equipment in home care. One of the concepts used in smart homes consists of using sustainable energy and relying on a Smart Grid network (SAPONARA; BACCHILLONE,

2012). Automated home systems should also manage the consumption and waste of water, natural ventilation, and illumination.

- Healthcare: Smart homes for old adults' care applications are growing at high speed worldwide as a response to the aging of the population. The smart home concept is a promising and cost-effective way of improving access to home care, intensifying preventive health instead of health recovering (CREAN; MCGEOUGE; O'KENNEDY, 2012), as well as the technologies (WACKS, 2002), (HASAN *et al.*, 2018), (TOSCHI; CAMPOS; CUGNASCA, 2017), reducing hospital contamination risk.

Traditionally, a family responsible for caring for old adults or convalescents often suffers from functionally disabling problems. This practice is becoming obsolete for social and economic factors of the modern way of life, making medical institutions and care houses more attractive.

Smart homes integrate technological solutions combining comfort with home care for convalescents, old adults, and people with special needs. Thus, many projects have been implemented around the world for these purposes in the academy (BAL *et al.*, 2011): WellAWARE, AlarmNET, AWARE, GatorTech Smart House, Georgia Tech Aware Home, Assisted Living Project (I-Living), Assisted Cognition Environment, CASAS, ORCATECH, MavHome, TAFETA Project, Gerontological Smart Home Environment, Casattenta Project IntelligentHouse, SOPRANO, CareWatch. The characteristics of these projects are described below:

- AlarmNET: Has been developed at the University of Virginia to provide health-care at home, residential monitoring, and independent living (Center for Wireless Health 2011) by using heterogeneous wearable and stationary wireless sensing devices, combined with a user interface, database, and decision logic program. Mobile body warning sensors provide physiological sensing for blood pressure, pulse rate, and movement (accelerometer) data. Stationary sensors collect environmental data such as ambient temperature, air quality, light, and user location (AL-SHAQI; MOURSHED; REZGUI, 2016). Data is collected, aggregated, pre-processed, stored, and acted upon according to the needs and conditions of the residents. The network can be tailored to the patient's medical needs and provide notifications (e.g., alerts to take medicine) using an in-network wearable interface. AlarmNet system is reported to support dynamically appending new devices to the network, which registers their capabilities and is initialized. This flexibility allows the system to change over time, including new sensors or if new required monitoring pathologies (BAL *et al.*, 2011).

- Assisted Cognition Environment: The Assisted Cognition Project is an interdisciplinary effort between many organizations with expertise in Computer Science for caring for Alzheimer's patients. The first category includes the University of Washington's Dept. of Computer Science and Engineering, the Dept. of Electrical Engineering and Intel Research. The the second includes the Alzheimer's Disease Research Center (ADRC), the UW schools of Nursing, Health and Public Policy, and Medicine, and the UW Medical Center. Assisted Cognition aims to develop computer systems that can provide such active assistance to an Alzheimer's patient (KAUTZ *et al.*, 2000). It involves the ability to sense the location and surrounding environment, interpret behavioral patterns, offer help via verbal and physical interventions, and alert caregivers during emergencies. Two concrete examples of Assisted Cognition systems are: an Activity Compass that helps reduce spatial disorientation both inside and outside the home and an Adaptive Prompter that helps patients carry out multi-step everyday tasks (BAL *et al.*, 2011).
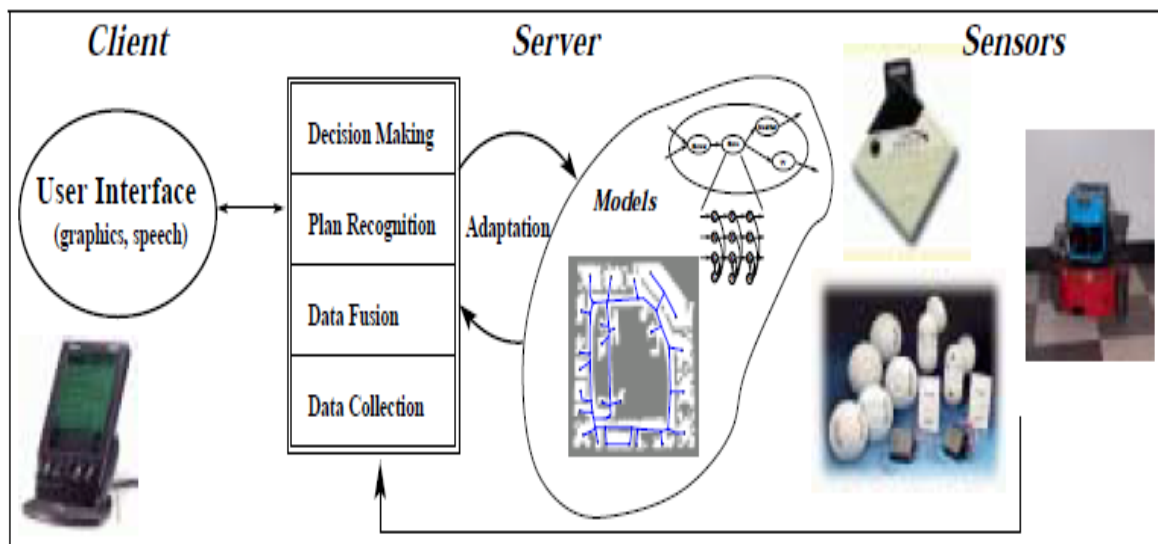

Figure 5 – Architecture of Assisted Cognition systems. Source: (KAUTZ *et al.*, 2000).

Figure 5 shows a layered architecture for the ACTIVITY COMPASS and ADAPTIVE PROMPTER based on linking sensor data to behaviors, behaviors to plans, and plans to potential interventions. Each layer takes in noisy and uncertain information, abstracts and fuses the data to reduce (not necessarily eliminate) uncertainty, and passes this higher-level view of the world to the next layer. Feedback from the effects of invention down through the layers improve the accuracy and effectiveness of the underlying models (KAUTZ *et al.*, 2000).

- AWARE: The project aims to conceptualize the living context of the elderly by introducing ubiquitous computing to provide important information to their family members who are concerned about them living alone. The key innovation is the

ability to distinguish a particular individual from others by detecting the person's location using force-sensitive load tiles on the floor that record footstep patterns, called ground reaction force (GFR), which consists of a metal plate supported by four industrial load cells to create a model of a unique footstep pattern for each individual (AL-SHAQI; MOURSHED; REZGUI, 2016). In this environment, human-home symbioses become essential to provide as seamless interaction as possible with the home. Wearable computers and intelligent environments deliver timely, personalized information and entertainment services at almost any time and in any context. The Aware Home infrastructure is an excellent chance to obtain general information about a user while at home, and a wearable computer can gather data wherever the user may go. The data gathered on the wearable might then be filtered and released to the environmental infrastructure as appropriate. On the other hand, the wearable may draw on the house's data resources to cache important information for the mobile user when away from the house. One of the applications of the tracking and sensing technologies in the Aware Home will be a system for finding Frequently Lost Objects (FLOs), such as keys, wallets, glasses, and remote controls. The system will use small, radio-frequency tags attached to each object the user would like to track and a long-range indoor positioning system to track these objects (KIDD *et al.*, 1999).

- CASAS uses machine learning techniques to identify behavioral patterns of the elderly suffering from cognitive decline using data from motion sensors. Tests involving cognitive health and dementia subjects showed that the implemented learning algorithm was able to identify the differences in activities; however, it could not distinguish the cause of differences, whether confusion was due to dementia or it is a simple mistake (AL-SHAQI; MOURSHED; REZGUI, 2016). One application that uses activity recognition is health-assistive smart homes and smart environments. Individuals need to be able to complete Activities of Daily Living (ADLs) such as eating, dressing, cooking, drinking, and taking medicine to reach an independent behavior at home. Automating the recognition of activities is an essential step toward monitoring the functional health of an smart home residents or intervening to improve their functional independence. The main contribution of this project is the introduction of an unsupervised learning algorithm to discover activities in raw sensor event sequence data and the combination of ACTIVITY RECOGNITION AND ACTIVITY DISCOVERY (AD+AR) to create patterns of patient behavior within the home (COOK; KRISHNAN; RASHIDI, 2013).

- Casattenta: Initiated by the Laboratory for ICT Technology Transfer in Bologna, Bologna, Italy to demonstrate a research project on Ambient Intelligence, Sensor Fusion and Wireless Sensor Networks (WSN). Aimed at integrating ambient intel-

```
:
2009-07-17  17:11:54.078001 D026 CLOSE Pat_4
2009-07-17  17:11:54.390001 M001 OFF Pat_4
2009-07-17  17:11:56.015001 M015 ON Pat_4
2009-07-17  17:11:56.671001 M001 ON Pat_4
2009-07-17  17:12:00.296001 M015 OFF Pat_4
2009-07-17  17:12:00.703001 M001 OFF Pat_4
2009-07-17  17:12:01.000001 M003 ON Pat_4
2009-07-17  17:12:04.921001 M003 OFF Cook
2009-07-17  17:12:06.296001 M003 ON Cook
2009-07-17  17:12:10.906001 M003 OFF Cook
2009-07-17  17:12:11.890001 M007 ON Cook
2009-07-17  17:12:15.828001 M007 OFF Cook
2009-07-17  17:12:24.390001 M009 ON none
2009-07-17  17:12:28.671001 M009 OFF none
2009-07-17  17:12:33.296001 M009 ON none
2009-07-17  17:12:37.296001 M009 OFF none
2009-07-17  17:12:42.171001 M009 ON Eat
2009-07-17  17:12:42.906001 M010 ON none
2009-07-17  17:12:46.187001 M009 OFF Eat
2009-07-17  17:12:47.203001 M010 OFF none
```

Feature Extraction
(aggregation of sensor counts and temporal features)

Feature Vectors with the associated labels

SVM Learner

Activity Models

Cook   none
Pat_4   Eat

Figure 6 – Flowchart for the AD+AR algorithm. Source: (COOK; KRISHNAN; RASHIDI, 2013).

ligence technologies, sensor fusion, and wireless communication in the form of a set of fixed and wearable sensors distributed alongside the monitored environment connected through a communication platform. The system was designed to support independent living by enabling the tracking and identification of critical situations such as the danger of falls and immobility conditions.

The Casattenta system implements the concept of an indoor environment aware of significant events related to the ambient and/or its inhabitants and capable of communicating remotely with interested observers. The system is based mainly on WSN technologies, which can be easily deployed in existing and even historical buildings without significant renovations or the need for advanced infrastructures. Furthermore, WSN suffers the advantages of self-organization, scalability, low power consumption, and relatively low cost. The system of this work is flexible and easily adaptable to different requirements in terms of sensors' type, number, and functionality. In addition, it makes use of low-cost standard heterogeneous technologies. The Casattenta system makes the domestic environment interactive and safer for its "interactive guests", i.e., people particularly exposed to risk of domestic accidents (such as elderly, but also impaired people, children) (FARELLA; FALAVIGNA; RICC, 2010).

- GatorTech Smart House: Developed by the Mobile and Pervasive Computing Laboratory at the University of Florida in collaboration with the university's College of Public Health and Health Professions, and with federal funding from the National Institute on Disability and Rehabilitation Research (NIDRR) (HASAN *et al.*, 2018). The GatorTech is based on several features such as smart floors for
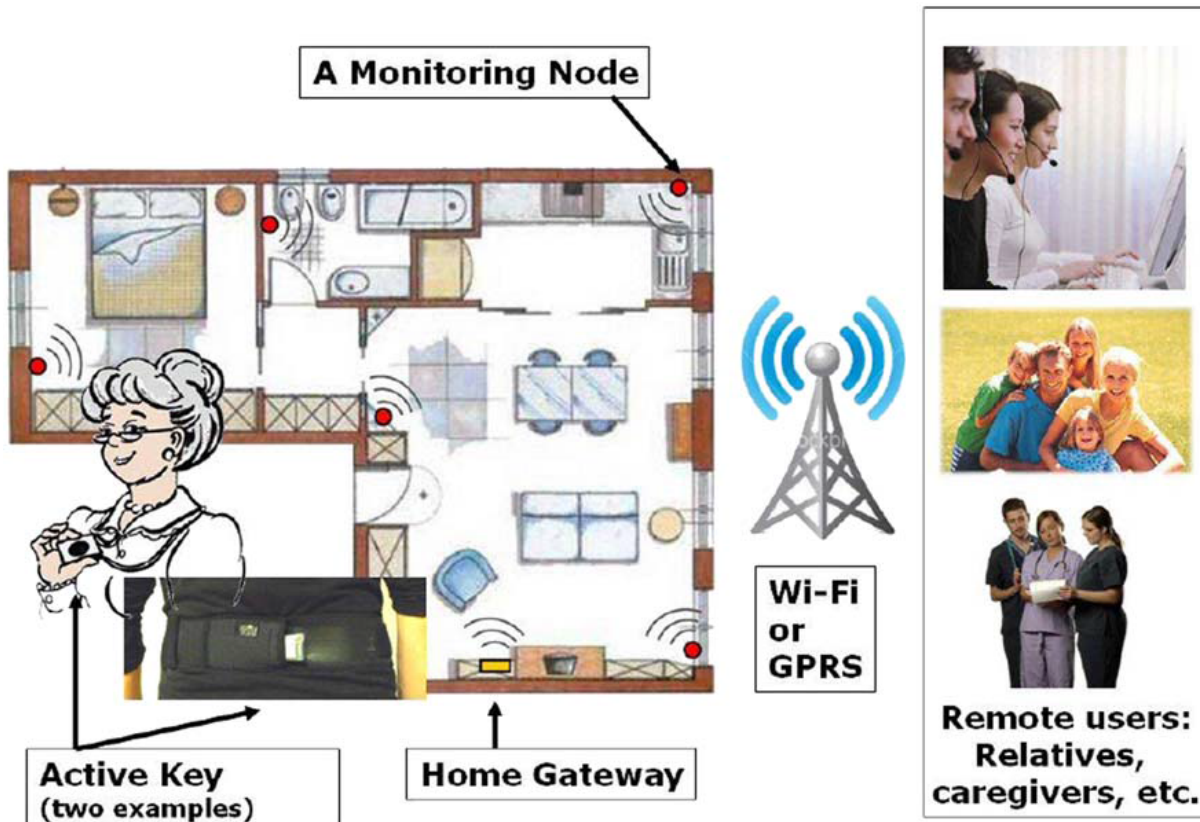
Figure 7 – Casattenta's general architecture concept. Source: (FARELLA; FALAVIGNA; RICC, 2010).

location tracking; smart plugs with Radio Frequency Identification (RFID) readers to detect connected appliances; a smart microwave oven to detect what food is being cooked; and the plug-and-play of sensors and actuators in the sensor platform. The overall system runs a generic Smart Space middleware built around the OSGi platform that stores service definitions for all hardware (sensors and actuators) inside the home, essentially turning the Smart Home into a software library and a runtime environment (BAL *et al.*, 2011). Figure 8 shows some points developed in the Gator Technological smart house.

GatorTech Smart House has a generic reference architecture applicable to any pervasive computing space. Figure 9 depicts the middleware containing different physical sensor platforms, service, knowledge, context management, and application layers (HASAN *et al.*, 2018).

- Georgia Tech Aware Smart Home: The Aware Home Research Initiative (AHRI) at Georgia Tech is devoted to the multidisciplinary exploration of emerging technologies and services for residences. Since 1998, a home was designed from the ground up with accessibility, computing, and sensing balanced with aesthetics. These applications cover the themes of aging in place, busy families, and children with special needs (KIENTZ *et al.*, 2008). The significant technologies developed are: "Digital Family Box", "Cook's Collage," "Gesture Pendant," and "Context- Aware
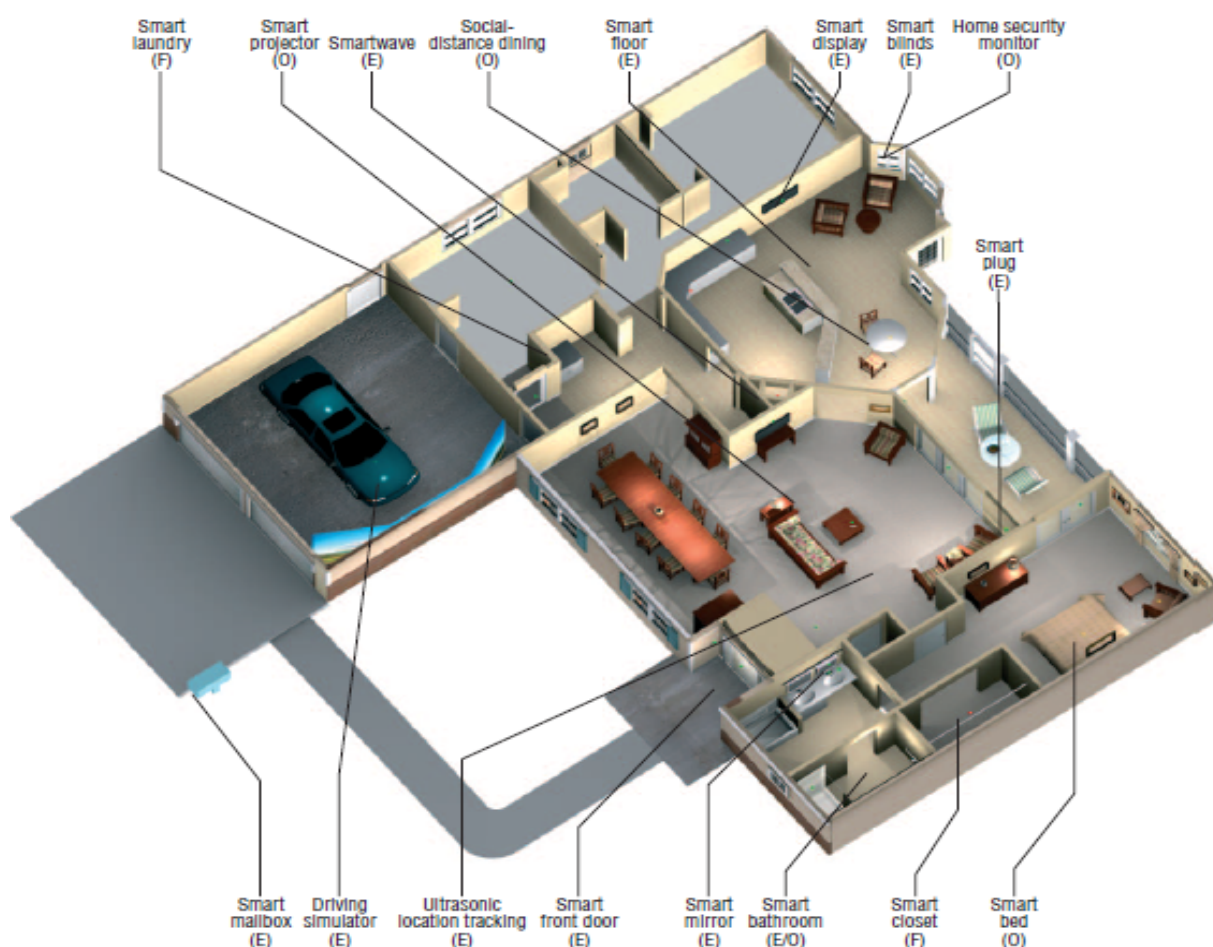
Figure 8 – GatorTech Smart House. Source: (HASAN *et al.*, 2018).

Universal Remote". Some multimedia technologies have been utilized to enhance the communication of elderly residents with their families. In addition, indoor location tracking services were developed, which range from relatively simple and robust low-resolution strategies, such as RFID, to more sophisticated and higher resolution, state-of-the-art computer vision solutions. Except engineering sensing systems to detect specific events (for instance, a fall), the research group has developed activity recognition methods to monitor the general activities of the occupants such as reading a newspaper, watching TV, preparing a meal, or using a blood glucose monitor (BAL *et al.*, 2011).

- Gerontological Smart Home Environment: this project was started by a network of research partners, led by the CTSB (Centre Scientifique et Technique du Bâtiment) and the Research Centre for Construction Techniques in France. The overall system has been designed to enhance independence of the people in loss of autonomy or at risk. GERHOME utilizes software solutions for automatic recognition and interpretation of human behaviors using real-time video images and real-time sensor data. The research initiative aims to design a communication platform,
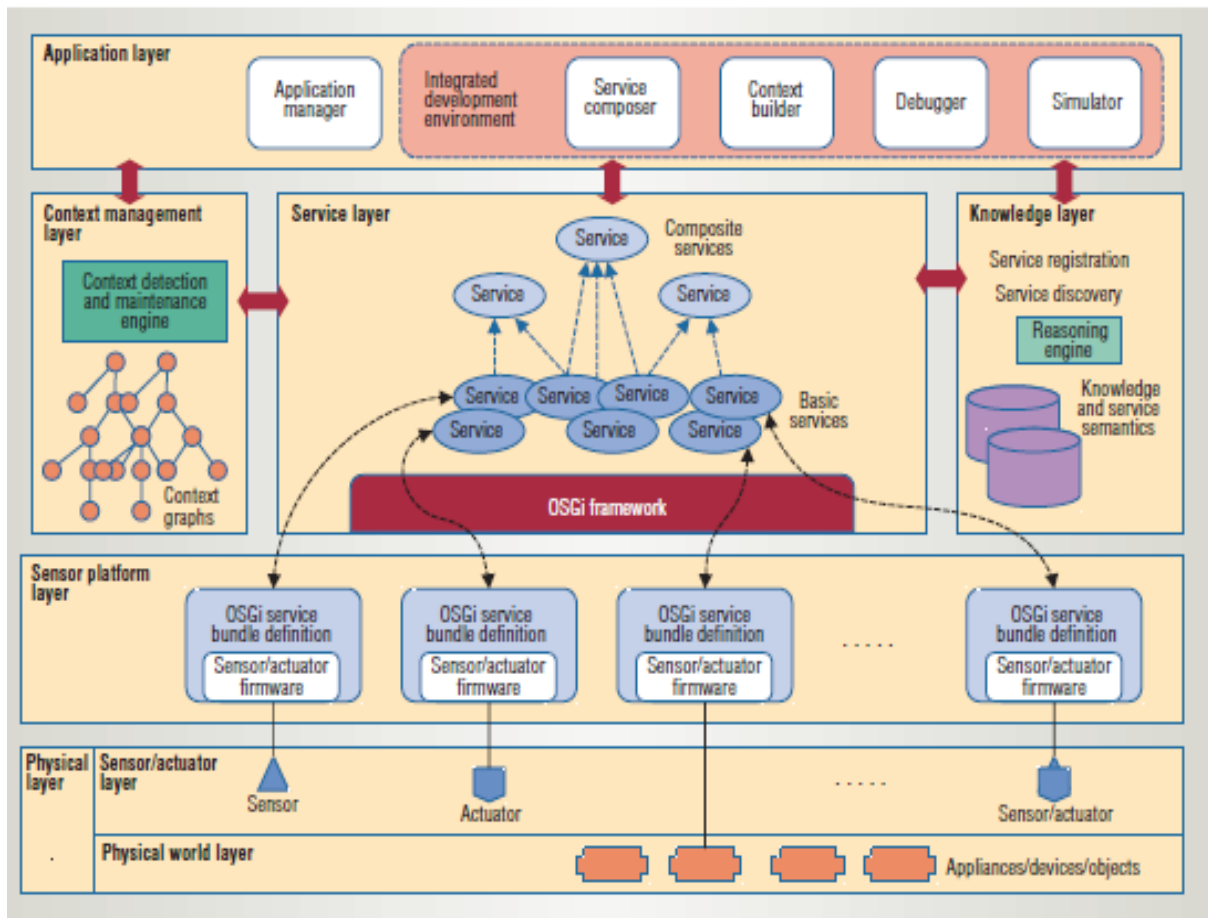
Figure 9 – Middleware architecture for GatorTech Smart House. Source: (HASAN *et al.*, 2018).

allowing the easy integration of sensors of various natures, coupled or not with existing equipment, within a total system, based on the existing standards (BAL *et al.*, 2011). The intention was to improve the feeling of independence of the elderly, complaining about the loss of autonomy. GERHOME's project presented a communication infrastructure based on intelligent agents allowing easy integration of different types of sensors within an existing system structure, based on an intelligent agent architecture (AL-SHAQI; MOURSHED; REZGUI, 2016).

- Assisted Living Project (I-Living): The University of Illinois at Urbana-Champaign has been designing, implementing, and evaluating with testable hypotheses an assisted-living supportive software architecture that allows disparate technologies, software components, and wireless devices to work together at a low cost, dependable, and secure fashion to enable older adults to regain their capacity for independent living. The assisted living system architecture attends: Activity Reminder, Vital Sign Measurement, Personal Belonging Localization, Personal Behavior Profiling, Emergency Detection (QIXIN *et al.*, 2006).

- MavHome: The name of MavHome comes from "Managing and Adaptive Versa-
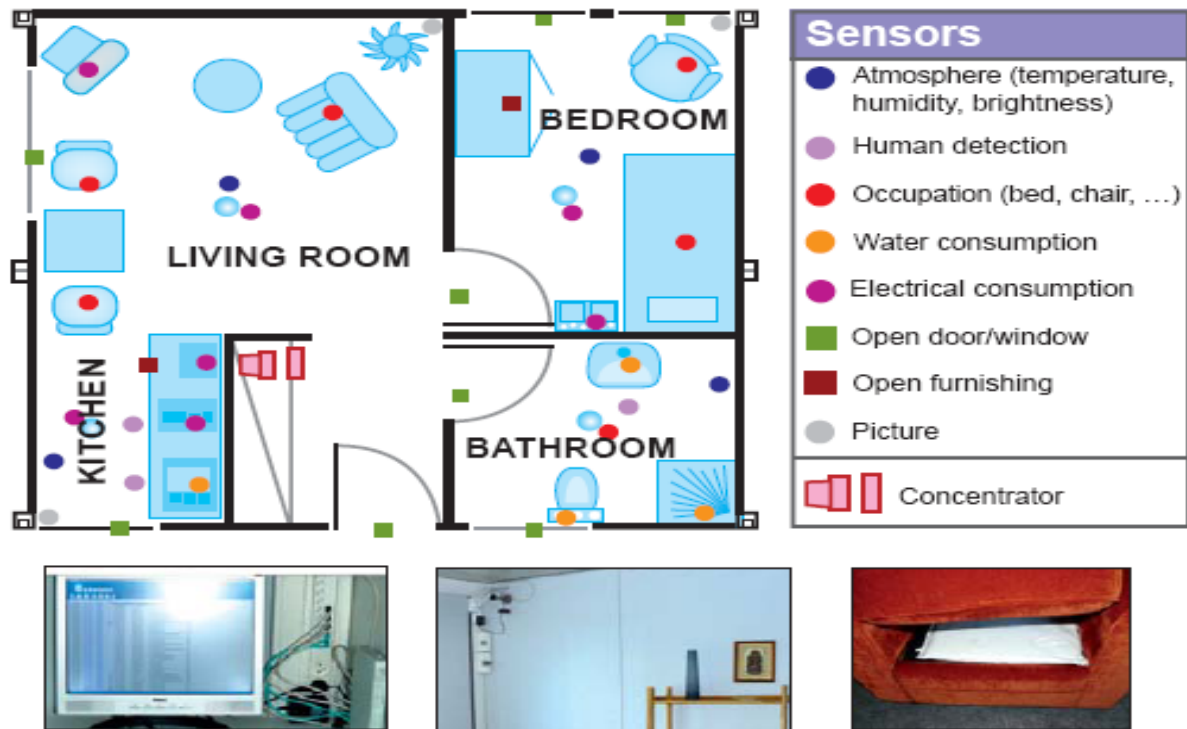
Figure 10 – GERHOME Layout. Source: (BAL *et al.*, 2011).

tile Home," and the focus is to maximize the comfort of its users and minimize operating costs. Developed at the University of Texas at Arlington, MavHome attempts to view the smart home as an intelligent agent that uses sensors and actuators to achieve its purposes. The agent architecture consists of four layers: a decision layer for executing actions based on information obtained from other layers; an information layer that gathers, generates and saves information that could be beneficial later; a communication layer that manages the information exchange between layers; and a physical layer, which consists of physical devices in the smart home space (BAL *et al.*, 2011). Figure 11 shows the architecture of a MavHome agent. The technologies within each agent are separated into four cooperating layers.

It is a bottom-up process where sensors monitor the environment (e.g., lawn moisture level) and, if necessary, transmit the information to another agent through the Communication layer. The database records the information in the Information layer, updates its learned concepts and predictions accordingly, and alerts the Decision layer of the presence of new data. During action execution, information flows top down. The Decision layer selects an action (e.g., run the sprinklers) and relates the decision to the Information layer. After updating the database, the Communication layer routes the action to the appropriate effector to execute. If the effector is another agent, the agent receives the command through its effector as perceived information and must decide upon the best method of executing the

desired action. A specialized interface agent provides interaction capabilities with users and external resources such as the Internet. Agents can communicate with other agents using the hierarchical control flow and information (COOK *et al.*, 2003).
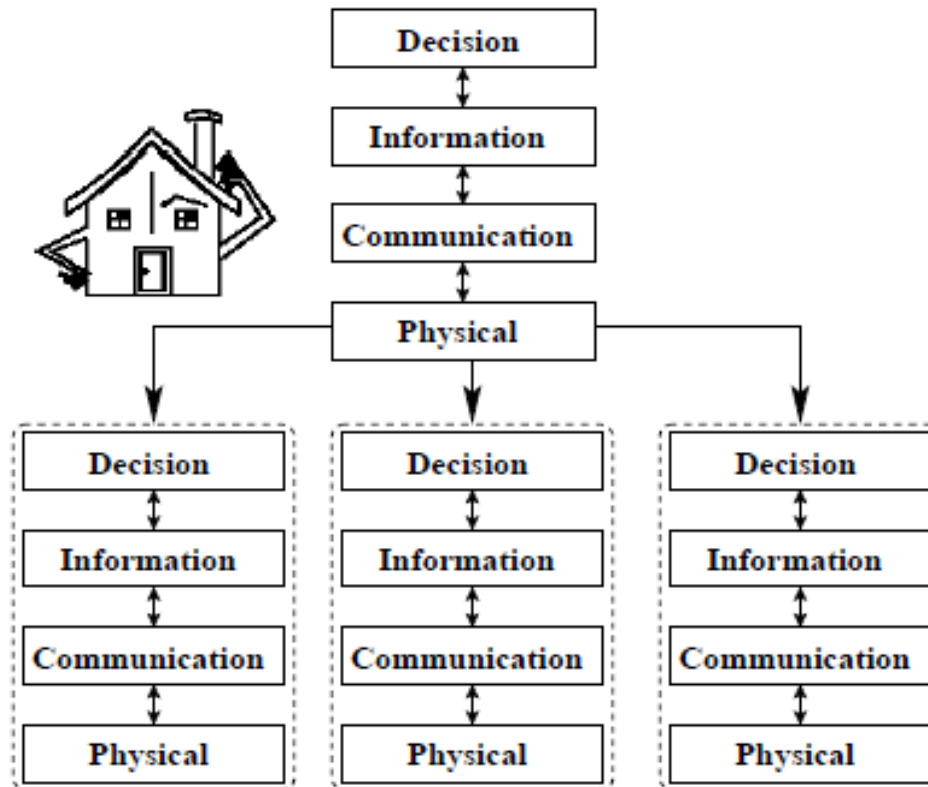
Figure 11 – MavHome agent architecture. Source: (COOK *et al.*, 2003).

- MIT House Project: The MIT House-n resulted from research at the Massachusetts Institute of Technology, focused on design elements and associated technologies for smart homes implemented in a laboratory facility equipped with sensors. A living laboratory facility called PlaceLab was constructed near MIT in order to facilitate experiments related to the project. The PlaceLab is a 93 square meters single bedroom condominium, equipped with hundreds of sensors that can be used to develop innovative user interface applications that help people easily control their environment, save resources, remain mentally and physically active, and stay healthy. The sensors are also used to monitor activity in the environment so that researchers can carefully study how people react to new devices, systems, and architectural design strategies in a complex context. Sensors are embedded in various locations in the lab. For example, cabinets in the lab contain sensor modules for measuring environmental quantities, infrared transmitters, and microphones. Video cameras and biometric sensors capture data about the users

and their movements. Data visualization and user interfacing were established by PDAs (BAL *et al.*, 2011).

- ORCATECH: (ORegon Center for Aging, Technology, Education and Community Health) is a collaboration of academic, industry, and community partners, financed by the National Institutes of Health. Devoted to the development of technologies supporting independent living for a wide range of requirements for older adults health monitoring and home care support. The system comprises intelligent bed sensors to track sleeping patterns and prevent the elderly from falling by turning on room lights automatically when the system detects that a person has awakened from sleep (AL-SHAQI; MOURSHED; REZGUI, 2016). Some significant technology studies related to senior independent living are as follows:

  - Intelligent bed that tracks sleeping patterns; preventing falls by turning on lights when getting up
  - Enabling the use of home-based technology for independent living
  - Home monitoring and cognition of Congestive Heart Failure (CHF)
  - Monitoring the seniors outside the home
  - Remote controlled telepresence in seniors' homes
  - Monitoring and information needs of the elderly
  - Technologies for monitoring health in the home
  - Social health monitoring and support (BAL *et al.*, 2011).

  Figure 12 shows the domain for an integrated system concept for living assistance.

- SOPRANO: The SOPRANO project is developing supportive environments for old people based on the concept of "ambient assisted living," using pervasive ICTs to enable older Europeans to live independently in their own homes. It is based on a combination of ontology-based techniques and a service-oriented device architecture. By separating system aspects such as sensors and actuators; context information and system behavior, SOPRANO provides a contract-centric framework for different solutions utilizing semantic technologies (AL-SHAQI; MOURSHED; REZGUI, 2016). The following SOPRANO scenarios of use have been developed (MÜLLER; SIXSMITH, 2008):

  - "Medication reminding" dealing with how to improve the situation of a person forgetting to take medicine;
  - "Open door" dealing with enhancing safety and security at home;

	Emergency Treatment Services	Autonomy Enhancement Services	Comfort Services
Indoor Assistance	emergency prediction emergency detection emergency prevention	cooking assistance eating assistance drinking assistance cleaning assistance dressing assistance medication assistance	logistic services services for finding things infotainment services
Outdoor Assistance	emergency prediction emergency detection emergency prevention	shopping assistance travel assistance banking assistance	transportation services orientation services

Figure 12 – Living Assistance Domain. Source: (NEHMER *et al.*, 2006).

- – "Safe," monitoring activity for signs of problems;

- – "Fall," adjusting care to increasing frailty;

- – "Easy to use home automation" demonstrating smart home components supporting independent living;

- – "Exercise," helping older people to do rehabilitation independently.

- – "Active," monitoring signs of problems and supporting good routines;

- – "Remembering," coping with cognitive aging;

- – "In Touch," combating social isolation;

- – "Entertained," countering boredom.

- • TAFETA: Technology Assisted Friendly Environment for the Third Age (TAFETA) has been developed by the Department of Systems and Computer Engineering, Carleton University, Canada. The project was built as a smart apartment, loaded with various sensors and actuators to detect and control environmental parameters (AL-SHAQI; MOURSHED; REZGUI, 2016). The project used and developed house technologies such as:

  - – Motion sensors – track the presence and motion of the resident throughout the apartment;

  - – Lighted pathway – illuminate the walkway from the bedroom to the bathroom to assist clients at night;

– Fridge sensor – provide audible cues to patients when the fridge door is open, sending an alarm to indicate potential distress and/or food spoilage;

– Pressure-sensitive mats – located under beds and chairs, these mats (made by Tactex Controls Inc.) integrate with custom software developed by Carleton University engineering students, which trigger additional sensors throughout the apartment through pressure. Researchers are currently developing new software algorithms to extract data from these mats in order to study breathing rates, sleep apnea, and bed entry/exit trends;

– Smart flooring – dual-stiffness was applied to reduce falls-related morbidity. This flooring, by SATech Inc., is installed in the bathroom.

- WellAWARE: Founded in 2000 by biomedical engineers and software developers at the Medical Automation Research Center at the University of Virginia. It provides an integrated structure comprising an unobtrusive sensor system and a user interface to enable professional caregivers and relatives to monitor and deliver support to older adults remotely. The system uses battery-operated proximity and motion sensors operating on Zigbee wireless protocol, deployed at several fixed objects in the house (furniture, walls, doors etc.). Significant components of WellAware include a system of sensors that track the movement of the household throughout their residence; a wireless data networking infrastructure; and central control unit and management software with graphical user interfaces for comparing the activities of the elderly household to a baseline of normality, interpreting the trend analysis and alerting caregivers to changes. Role-based website access is provided to the caregivers, who constantly monitor the developing conditions and apply earlier intervention for more serious chronic or acute health issues (BAL *et al.*, 2011).

- CareWatch: was developed for monitoring sleeping patterns of cognitive-declined elderly, activating notification systems for care providers. It has a view for preventing unsupervised home exits to release some burdens from the care providers, especially during the night. The system is designed to increase the quality of life for both the care recipient and the caregiver (AL-SHAQI; MOURSHED; REZGUI, 2016).

Other projects are implemented at industrial levels (BAL *et al.*, 2011):

- IST Vivago® WristCare: The VTT Technical Research Centre of Finland has been working on Pervasive Health Technologies Research for health care and independent living since 1993. The research center focuses on the application of pervasive computing technologies for healthcare and wellness management on two main

themes: (i) technologies for healthcare professionals in the hospitals; (ii) technologies for individuals outside the hospitals such as personal wellness and disease management (e.g. diabetes, fitness) and independent living (PAAVILAINEN *et al.*, 2005).

- Intel Proactive Health Lab: Intel established Proactive Health Lab in 2002 to explore ubiquitous computing technologies to help people proactively manage their health and wellness in their home and daily lives, preventing or delaying disease onset. The Digital Home Technology is the core to achieving Intel's aging in place strategy, which involves multitudes of consumer electronics (e.g. TV, clock, telephone, PC, PDA) to link together in a wireless sensor network. Prototypes of smart homes were built and equipped with a network of sensors (e.g. motion sensors, RFID, motes) that tracks and monitors everything from cooking habits to purchasing activities to level and quality of physical movement. By monitoring changes in activity patterns or levels, it is possible to detect early onset of dementia or provide appropriate levels of assistance to support and enhance people's abilities to conduct normal daily activities (DISHMAN, 2004).

- Shimmer Platform: Shimmer (Sensing Health with Intelligence, Modularity, Mobility, and Experimental Reusability; is a small wireless sensor platform that can record and transmit physiological and kinematic data in real-time. Based on an open, flexible architecture, Shimmer incorporates wireless, tiny, and wearable ECG, EMG, GSR, Accelerometer, Gyro, PIR, Tilt, and Vibration sensors. Each device in the ad-hoc network collects data, relays the collected data to its neighboring devices, and to a specified destination where it is processed. This sensory input, when gathered from all the locations and analyzed by more traditional computers, paints a comprehensive, high-resolution picture of the surroundings in real-time. The sensor platform overcomes issues of size, weight, and low-power-based communication capabilities, which have constrained wireless sensing to date (BURNS *et al.*, 2010).

- ExperienceLab - Philips: Philips research group in Eindhoven, Netherlands, has built a research lab for testing Ambient Intelligence solutions. The laboratory features speech recognition and user positioning along with several screens for displaying information to study how users deal with new technologies in a home setting. Microphones and cameras are mounted in every room. Tests were conducted with family members, who were able to share digital media and discover new ways of interaction. Equipment can be controlled in new ways using gestures and speech commands, leaving the user free for other activities at the same time (BAL *et al.*, 2011).

- Philips Lifeline: Belonging to Philips Independent Living Solutions, it is a lifeline medical Alert service providing a simple and reliable one-button triggered bi-directional hand-free communication channel. It groups well-trained Response Center Associates to promptly arrange for assistance and follow up to ensure proper care to Lifeline subscribers. An Auto-Alert option was recently added to the Lifeline product with embedded fall detection unit that can automatically send a help signal when a person is unable to push the help button in case of emergencies (BAL *et al.*, 2011).

- Home Assurance: Home Assurance is a project run by General Electric. The project aims to provide an unobtrusive "watchdog" in a home that will automatically identify and alert caregivers to irregular behavior by the person living in the home. Wireless security sensors placed strategically in a home electronically capture and report routine movements and activities - the opening and closing doors and motion through rooms like bedrooms and kitchens. Sophisticated algorithms organize that data into models of "normal" routines for that specific household. Current activity is constantly compared to the regular model. The system generates summary reports of activities that a caregiver can monitor via the Web. It can also alert them via phone, e-mail, or pager that something unexpected has occurred. Long-term trends can be viewed to see if the behavior is changing over time, indicating that a higher level of care is needed (BAL *et al.*, 2011).

Although these projects tend to focus on aspects such as: monitoring the activities of the householder and the living environment to ensure the safety of residents, detecting the physiological and mental condition of the householder, automating tasks that a householder is unable to perform, alerting and preventing the householder of potentially dangerous activities, alerting informal caregivers (family members), formal caregivers (nurses, doctors or superintendents), linking them to their families and communities (BAL *et al.*, 2011).

2.5 Product-Service Architecture

Digital convergence launches innovation paths that are beginning to break through the industry, presenting competitive innovations and new opportunities for a better quality of life and, at the same time, improving efficiency in caregiving or the home office. New home systems bring new levels of communication and integration with computer-assisted collaboration. The collaboration explores the full potential of distributed agent systems to reduce the size of current automated facilities, reduce pollution, save energy, and can relieve the pressures on the health system, public or

private. In industrial applications, the old approach is based on restricted communication and has been replaced by a solid and well-defined communication architecture using increasing levels of digital automation. They share advantages already available for other interactions, such as open and agile communication, exchanging data, and exploring and enabling interoperability and virtual operations. This new approach reinforced the need and ability to merge between products and services (NOF; SILVA, 2018).

As defined in (NOF; SILVA, 2018), the key concept is a change in distributed and collaborative architecture towards a distributed set of cyber-physical entities with service orientation: enhanced cells, startups, and other production systems, supply sources, etc. The current competitive environment imposes a set of particular requirements on the company's operation; among them, the need to operate with greater flexibility and agility and to adapt efficiently to customer demands in a global environment. Marketing is vital for positioning and selling a product or service.

The main objective of an SOA (Service Oriented Architectures) is to build the different information systems for a company on a set of computer standards with the aim that all of them, even those made with different technologies, can operate in an integrated way and without dependencies between the same. Services are those computer modules that offer business functionality by themselves and whose operation is independent of the status and characteristics of the rest of the services with which it is related.

The main functional characteristics of SOA solutions are the following (MEZO; CHAPARRO; HERAS, 2008):

- Technological infrastructure comprises independent services: the different services are joined in a network to compose the organization's business processes. The rest of the applications can use them.

- Ability to reuse services: many of the services can be reused in different business processes once they perform standard functions, so the implementation of new processes only requires the development of its own functionalities. These functional characteristics result from a set of logical and technical characteristics typical of this type of solution.

- Low level of service coupling (Loose Coupling): each service must be independent of the rest of the services connected to the same network.

- Independence between the services and the technical characteristics of their implementation: to favor independence between the different services, the functions they perform must be independent of the technical characteristics of their implementation. Using standard protocols guarantees that applications of any technology can use them.

- Use of standard interfaces: standard interfaces are necessary to allow services of different technologies and data formats to exchange information without resorting.

Designing a digital factory—in a version that goes beyond the limits of the current Industry 4.0 and touches Industry 5.0[4]—it is necessary to start with a method directed to systems of systems and propose the proper adaptations.

A design model can be summarized as a layered system (Figure 13) where the first layer is the conception and requirement layer (CoL), the second layer is the architecture layer (ArL); and the last layer is the assignment layer (AsL). Layered approaches have been used in software engineering and multiagent systems since the 1990s but have only currently reached the mainstream of Systems Design. Today, there are already commercial environments for Systems Design and Systems of Systems Design, applying this approach (NOF; SILVA, 2018).
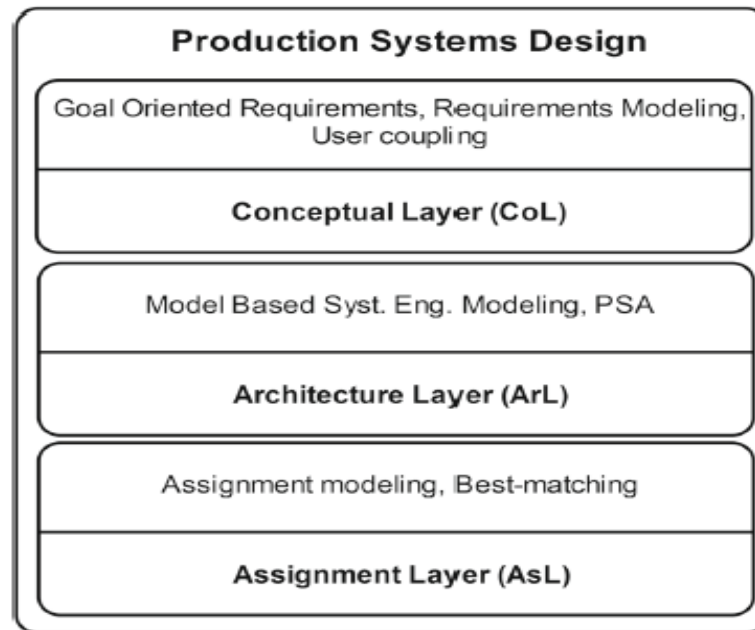
Figure 13 – Layered systems design for Industry 4.0. Source: (NOF; SILVA, 2018).

A Product-Service[5] Architecture (PSA) is based on a service network. It includes a design framework where consumers can enter with generic intentions to be transformed in requirements, automatically or with the help of system operators (where the goal is to get a match between the demand for services and the service provision). Another service supporting this framework introduces a model for coupling service consumers

---

4   Industry 5.0 provides a vision of an industry that aims beyond efficiency and productivity as the sole goals and reinforces the role and contribution of industry to society. It complements the existing "Industry 4.0" approach by specifically putting research and innovation at the transition to a sustainable, human-centric and resilient industry.

5   The product-service concept takes conventional products as a resource to provide services and matches them with the user, producing powerful co-creation of value, replacing the dichotomy between products and services.

and service providers (SILVA; VITAL, 2020).

The PSA (Figure 14) is an abstract reference model to the architecture layer, Figure 13, into a distributed composition of production units (PUs) or service components. Each component comprises persons, agents, machines, and other product/server units in a recursive system of systems approach. Each component delivers a service or product-services in a workflow that results in a larger product-server.
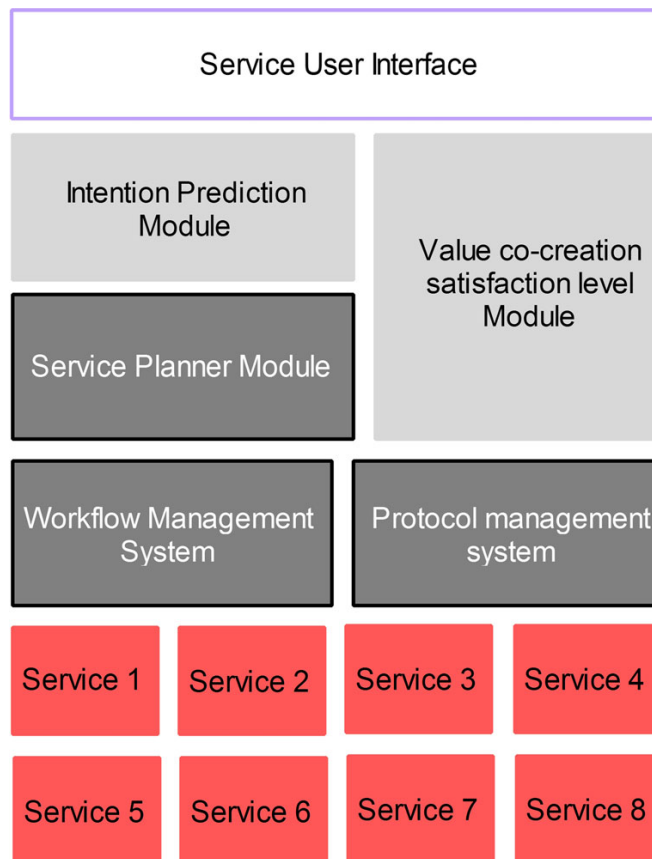
Figure 14 – Product-Service Architeture (PSA). Source: (SILVA; VITAL, 2020).

PSA architecture denotes a cloud of production unities (the red boxes at the bottom of the picture) that will form a production arrangement (or services) and compose a product/service to be delivered to a customer - following a planned workflow defined by the service provider. The workflow also implies resource sharing and exchange of information between sub-services or a combination of them. Production actions are partially ordered (planned) or follow a schedule to provide the deliverable product/service. The Protocol Management System should manage communication between elements. The Service Planner arranges actions and sub-services calling. In order to reach the intended value of co-creation, it is necessary to predict customer satisfaction derived from the co-created value - an interface that captures some client inputs and predicts clients' intentions. As the plan is executed, a satisfaction module should measure or anticipate clients' reactions and adapt the plan if the value co-creation does not reach the required level (de S. Dutra; SILVA, 2016).

This dissertation will use a service-oriented architecture to model healthcare and home care systems organized by layers. We assume that the home automation system is service-oriented and will support the design of an intensive healthcare system on top of it, which is also a service network combining several different features, such as those listed above, implemented by different institutions and labs.

2.6 eXtensible Markup Language (XML)

XML is a language recommended by the World Wide Web Consortium (W3C) for creating documents with hierarchically organized data, such as text, database, or vector drawings (TECHNOLOGY; COMMITTEE; COMPUTER, 2005). The XML language is classified as extensible because it allows defining markup elements.
XML provides a basic syntax to share information between different computers and applications. When combined with other standards (PACINI, 2002), (PARK *et al.*, 2007), it makes it possible to define a document's content separately from its format, making it simple to reuse the code in other applications for different purposes.

Basic features of XML are:

- It is a plain-based text. XML represents data in a much more natural way for human beings when compared to other formats (e.g. ".csv" file, JavaScript Object Notation (JSON) file, relational tables).

- It can represent the relevant data structures of computation: lists, records, and trees.

- It is editable, due to the popularity of XML these days, with different levels of automation, in any environment: Since old txt editors until more sophisticated tools, programmers-oriented, such as Integrated Development Environment (IDE), or content-oriented, such as EXtensible HyperText Markup Language (XHTML) editors, both have been adapting to handle other XML formats, interpreting Document Type Definition (DTD), eXtensible Stylesheet Language (XSLT) or XML Schema Definition (XSD).

There are some basic rules for a good formation of an XML file (Source: <https://pt.wikipedia.org/wiki/XML>):

- Every XML document, in addition to the introductory tag, must have a single element (tag) that serves as the root for all other elements of the document, as shown in Appendix C.

- XML is case sensitive, so it differs from case to case, demanding some caution with using CamelCases (compound words).

- Every XML element must be started and closed except the one that defines the XML version used and other single tag definitions, eg <system opera="on" where="here" />.

- XML comments are the same as HyperText Markup Language (HTML) (<!–comment–>).

Recently, XML has been selected as a transfer language in different situations, especially in design. Silva et al. (SILVA *et al.*, 2021) proposed a requirements cycle where a diagrammatic goal-oriented requirements specification is translated to a formal representation in Petri nets. That was previously done using UML as a starting representation (SILVA *et al.*, 2022), but could not be done so far with KAOS representation for the lack of an XML definition of his diagrams. One of the contributions of this dissertation is a proposition for a KML, that is, a KAOS Markup Language.

2.6.1   *Petri net Markup Language (PNML)*

Petri nets representation will be used to formally verify requirements proposed by Silva, JM et al. (SILVA *et al.*, 2022). To achieve that, the KML definition should be translated to an XML description of Petri nets (Place/Transition). In what follows, we will give a brief definition of PNML.

PNML is a proposal of an XML-based interchange format for Petri nets (PN). It is an attempt to standardize the sharing of information from models defined in PN for various tools that use the technique (MA; XU, 2009), (LEE; SHARDA; BANERJEE, 2007), (DAVIDRAJUH, 2008).

The standard ISO/IEC 15.909 defines the basic types: Place/Transition, High Level, and Asymmetric nets (ISO/IEC 15909-1). ISO/IEC 15909-2 defines an interchange format PNML (Petri NetMarkup Language) to support the exchange of models between different tools and analysis environments. User extensions (ISO/IEC 15909-3) are accepted, since they respect the formal definitions of ISO/IEC 15909-1. Extensions could stand for hierarchical nets, fusion places and transitions, gates, time, and object-oriented nets. More information about the standard can be found at <www.iso.org/standard/67235.html>.

The PNML file has in its specification all the elements, Appendix B, that make up a PN model. PN model comprises the elements: place, arc, transition, and tokens. Figure 15 presents the relationship between the main metadata entities and their respective interpretations in the graphical model and XML file.

Graphic Element	Metadata Entity	XML element
	PetriNetDoc	<pnml>
	PetriNet	<net>
⊙	Place	<place>
❙	Transition	<transition>
⟶	Arc	<arc>

Figure 15 – Relation of Petri nets and XML Elements with PNML Entities.

This dissertation does not contribute to Petri nets and its property analysis. However, this representation and formal analysis will be used to formal verification of process requirements for services that connect the healthcare sequence of actions and the calling of residential automation systems.

PROPOSED WORK

This chapter will present a proposal to develop a home care system, linking formal methods to design automation projects with healthcare and telemedicine. The proposal is based on requirements modeling cycle that begins with a semi-formal description of the requirements elicited from different stakeholders. The focus is on the early design phase, starting with modeling and analyzing distinct viewpoint requirements, using a goal-oriented approach represented by KAOS diagrams. Formalized in Petri Nets, a match will be made between the healthcare services layer and the domotic infrastructure. Furthermore, a multilayer architecture is presented to support the design of a healthcare system in a domain that inherits a legacy domotic system.

The contribution of this work is precisely the development of this design process which includes a consistency analysis of the matching using goal-oriented requirements formalized in Petri Nets. The result will open the possibility of preparing homes for intensive care by adapting existing automated domes, detaching and integrating domotics from healthcare.

3.1 Proposal of a design environment for Assistive Smart Homes

The hardest part of system development is precisely knowing what to build. The conceptual work is as complex as establishing detailed technical requirements, including customer interfaces, resource machines, and other sub-systems. Therefore, the increased complexity of developing automated healthcare systems becomes challenging for specialists in medicine and engineering. A meticulous work like this does not admit mistakes, especially in the early phase. Such mistakes would be difficult to fix in the design and deployment processes. Therefore, a formal approach should clarify and validate the efficiency in different phases of the project:

- Requirements (what must be done and why)

- Design (how to achieve the system's goals directly and with the lowest possible cost and efficiency)

- Implementation (describing deployment alternatives, interacting with end-users, and anticipating how to discard the system at the end of its lifecycle)

- Deployment (how to get feedback from the system working with the surrounding environment)

- Maintenance (how to use documentation and service orientation to handle system evolution)

Formal models should follow all these phases, ideally using the same formal representation. As mentioned before, we capture the requirements into a semi-formal goal-oriented diagram following a refinement cycle proposed by D-Lab and shown in Figure 16: the Model-Based Requirements Engineering (MBRE). The MBRE concept supports the requirements engineering cycle, modeling the requirements elicited in harmony with the domain environment (BKCASE Editorial Board, 2021). By stepwise refinements, we analyze requirements by formal verification in each cycle based on conservative extensions of the model.
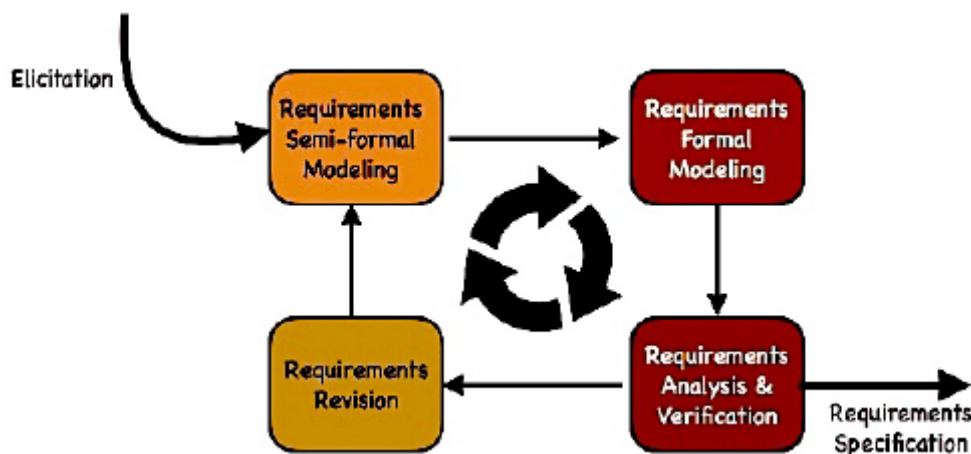
Figure 16 – Model-Based Requirements Engineering Cycle. Source: (SILVA *et al.*, 2021).

The GORE approach with MBRE suits the health systems design as a critical service, avoiding potential lethal failures for the patient/customer. The Healthcare system is a subset of the health system domain, but its development also demands a formal requirements cycle. Consequently, it is possible to guarantee integrity, correctness, relevance, consistency, traceability, and unicity of the *"System-To-Be"*. Also, GORE is an approach suitable to face the dichotomy between functional and non-functional requirements, which could be critical when the goal is to produce a failure-free design.

Also, growing user needs and diversity of scenarios for healthcare systems require a more systemic approach (BKCASE Editorial Board, 2021). Therefore, the process must begin by modeling the existing system or the "system-as-is" to match its evolution to a "system-to-be," allowing the integration with a previous legacy system. Based on this model, intentions and expectations concerning the "system to-be" will be added using a goal-oriented approach. Figure 17 depicts the main steps for the proposed model.
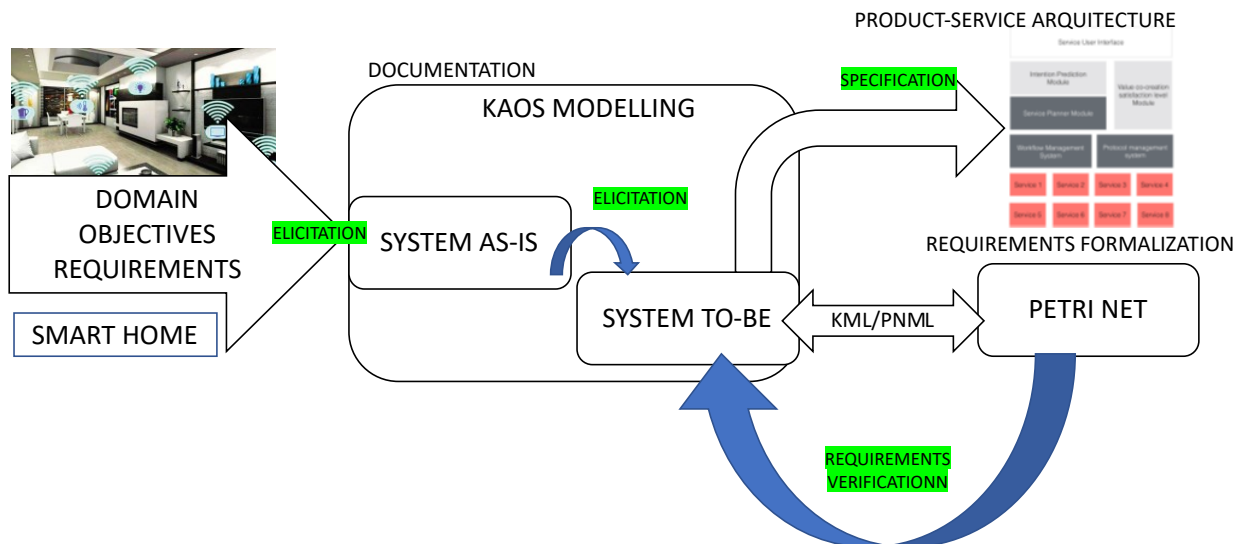
Figure 17 – Design environment. Source: Author.

Although the goal-oriented approach uses a semi-formal language (as the conventional one, based on UML), it allows requirements to be formalized early. Thus, it is possible to simulate and validate processes involved in healthcare services by transferring a semi-formal representation to a formal one, such as LTL or Petri Nets. Such a process is highly relevant since critical systems need simulation and validations to avoid admitting failures during their development and implementation.

In addition, the method proposed consists of a multilayer architecture, where all the systems or processes involved will match into one that achieves the main objective proposed, with the end-user participation, reinforcing the service approach.

In the following, we will describe the MBRE cycle in more detail.

3.2 Model-Based Requirements cycle for healthcare service

In traditional systems engineering, all data are represented as textual specifications or schematic drawings. In the last 20 years, models have been introduced as a better way of creating, managing, and verifying data than textual specifications. The requirement cycle in MBRE for a healthcare system is composed of the following steps:

3.2.1   Step 1: Domain Data Collection

The domain of action of home care is the set of services, whether social or health, that offers assistance to users or patients at home (MCGEE-LENNON; GRAY, 2007). For this, it is necessary the contribution of people and the use of technologies working together to capture, analyze, manage, and distribute information. The social and professional aspect of home care, made up of people, is known as the home care network and involves the entire set of people and organizations that are related to the patient attended at home (MCGEE-LENNON, 2008).

Home care systems are characterized by being multi-user, multi-stakeholder, collaborative, and distributive. Users of the system are generally patients with chronic diseases or health problems whose medical needs can be managed at home. Stakeholders are diverse, such as doctors, hospitals, caregivers, nurses, insurance companies, home care agencies, pharmacies. (DAIMI *et al.*, 2010).

Following The Seven Samurai modeling approach (MARTIN, 2004), the target system P is defined in an environment domain d (domain where the interactions with P are intensive enough to deserve to be considered), which is inserted in a larger application domain D. The requirements cycle begins by obtaining, in natural language, the properties of the environment d and specifying the problem P, also in natural language. There is no way to know if the requirements obtained are a model or are consistent until the next modeling step (semi-formal) is performed. Thus, in the very beginning, modeling the "System As-Is" is essential to capture the consistency of the legacy system - if it exists [6].

3.2.2   Step 2: "System As-Is" requirements specification

The "System As-Is" is modeled using the KAOS method with the previously collected, classified, and organized domain information. Different models (SAPONARA; BACCHILLONE, 2012), (CHAN *et al.*, 2008), (ALAM; REAZ; ALI, 2012), (WILSON; HARGREAVES; HAUXWELL-BALDWIN, 2015), (AL-SHAQI; MOURSHED; REZGUI, 2016), (HASAN *et al.*, 2018) compose the legacy systems to analyze the requirements and properties established for homecare systems. A generic vision of this system service is obtained by analyzing the coupling with end-users and its value co-creation. It is not common to detect problems at this step once the "System As-Is" exists and work with the initially specified requirements. If a legacy system does not exist, a model extracted from an initial analysis of stakeholder requirements should replace it.

---

[6]   In cases where a legacy system does not exist, stakeholder and user contributions should be modeled in a first approach, capturing the process that will become in the "System As-Is"

3.2.3   Step 3: "System To-Be" requirements specification

After understanding and analyzing the legacy system (or the stakeholder's and user's expectations), start the requirements elicitation for the "System To-Be," identifying new demands from stakeholders, end-users, and the surrounding environment. Viewpoints from different stakeholder categories (caretakers, family, nurses, doctors, and health systems) should be harmonized to suit the leading service, even at a high level of abstraction.

Some functional requirements come from the medical stakeholders and are directed to patients/costumers, such as patient monitoring through medical sensors; records should be updated in the cloud; communication is established with the care services (insurance, company, government). Regarding non-functional requirements, there are, for instance: performance, usability, system usability, security, privacy, maintenance, and reliability (MCGEE-LENNON, 2008).

"System-To-Be" modeling should capture objectives, obstacles, threats, conflicts, and risks for their subsequent management.

3.2.4   Step 4: Requirements formalization

Early requirements are usually written in natural language, either because of the difficulty of using formal languages or because it is too early in the conception process to introduce formal representations (they do not compose a model). The main issue with writing requirements in a natural language is that they cannot serve as inputs for automated verification techniques. Thus, a formalization process consists of writing requirements using a formal mathematical representation. It can be a challenging task if done directly from an informal requirement (PERES; YANG; GHAZEL, 2012).

Distinguishing between functional and non-functional requirements can lead to uncertainty, such as whether all requirements are fully elicited (requirement set completeness). The proposed method uses objective-based methods to facilitate semi-formal modeling and formalize partial (complete) models in cycles, eliminating the choice or priority dilemma between the functional and the non-functional issues. In a first approach, requirements are first represented in KAOS, collapsing formal and informal issues in the objectives.

The KAOS method can be formalized on LTL (Linear Temporal Logic), which is widely used in software development projects. For this proposal, Petri nets will be the formal representation. A KML file is synthesized from the KAOS model and used in the following to translate the requirements to Petri Nets. Appendix C shows the definition of KML. The KML is transferred to a PNML file, captured by any tool that follows ISO/IEC 15.909, to generate a PN model, which workflow is analyzed and formally verified.

The choice of PN for formal analysis and verification of requirements is justified by its capacity to be used in different design phases, reducing maintenance and more translations. It could also favor reusability, configuring a global system and process representation, associating the structure and dynamics (GONZÁLEZ; SALMON; SILVA, 2011). It is also a suitable formalism to introduce the matching between the layers (health layer and domotic layer), managing control and resource flow simultaneously.

3.2.4.1 Matching Layer Requirements

Working with requirements can be intensive work if performed manually. This work proposal leads to an architecture based on services located in the cloud, as shown in Figure 18. The transfer KML/PNML was prototyped (its encapsulation is proposed for future works), is composed by the following elements:

1. User interface: Devices through which the user will access the different available microservices.

2. API-gateway: The term API is an acronym for "Application Programming Interface" APIs are a way of integrating systems, allowing information to be exchanged between systems with different programming languages, ensuring data security.

3. Microservices: Microservices refer to certain functionality, which can be divided into smaller fragments so that each element can count on development, corrections, and changes individually without impacting the entire application.

4. Data storage: KML or PNML files generated and used by the different microservices will be stored.

The following services compose the modeling:

- Calling the K4S service will execute the tools for modeling KAOS diagrams, generating or reusing the KML files, using the code shown in Appendix C.

- Calling the K4S2PN service will perform the transfer in both directions (KAOS<—>PNML), executed by generating and storing the corresponding files according to the respective service. The flowchart, Figure 20, shows a sequence of logical operations necessary for this transfer.

- By calling the PNS service, the Petri Net modeling and analysis tools will be executed, generating the corresponding PNML files. An inverse process can be carried out from the PN to the objectives model. The requirements can be reused and adapted to new developments, reinforcing MBRE reusability (the reverse algorithm is under development).
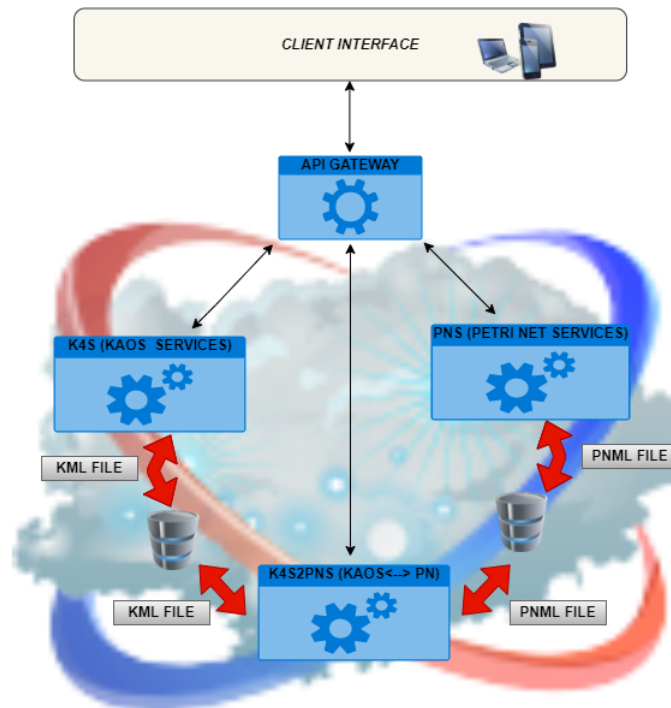
Figure 18 – Proposed service architecture for KML<–>PNML transference.

3.2.4.1.1   Transferring KAOS to Petri Nets

PN verification relies on mark flow and property analysis (Murata, 1989) classified into functional and structural properties. A transfer process between KAOS and the Petri Nets should, for instance, preserve invariants.

Some PN extension will be used in this work to represent concepts of the KAOS in PN, shown in Table 1. Inhibitor arcs allow a transition to check for the absence of a token. They have been introduced to deal with a synchronization problem not expressible in classical Petri Nets. They are just classical elementary nets extended with inhibitor arcs (ALQARNI; JANICKI, 2018). An inhibitor arc (IEC/ISO 15909-3), Figure 19, connects an input place to a transition, and enables the transition when there is no token in the input place connected to that transition (ZAMANI *et al.*, 2011).
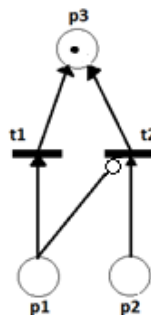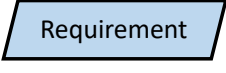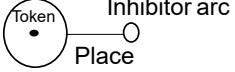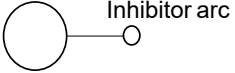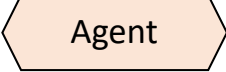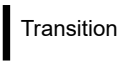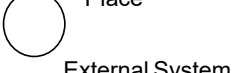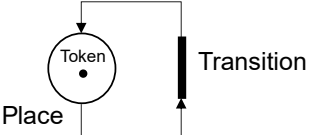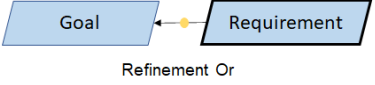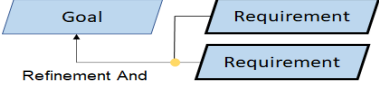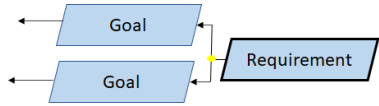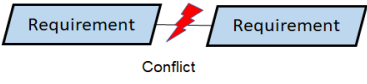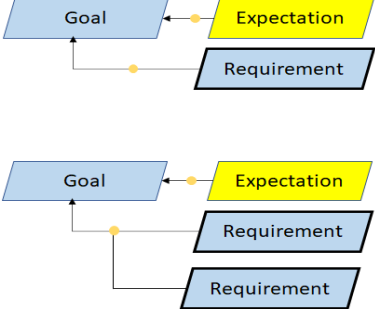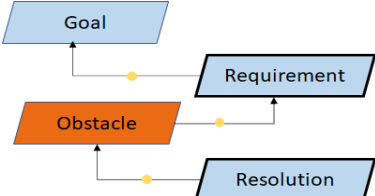
Figure 19 – Inhibitor arc in Petri net graph.

Table 1 – Guideline for KAOS-PN transference

KAOS ELEMENTS		PN CORRESPONDENCE
Goal	Describes an objective to be achieved by the system or one of the subsystems.	◯ Place
Requirement	A low-level objective with clear satisfaction criteria that can be used in test routines. Satisfaction of the requirements should be reflected (using the objectives diagram) in the justification of other objectives related to these requirements.	◯ Place
Obstacle	An unfavorable condition or constraint to the satisfaction of goals, usually originating in the context or domain of the overall goal.	Token ◉ — ◯ Inhibitor arc Place
Expectation	Denote results expected by the agents. It does not have clear criteria for its satisfaction. Therefore their satisfaction - partially defined - does not affect the satisfaction of the associated requirements. However, the satisfaction of expectations can influence the satisfaction of agents, which is important if they are part of the coupling of services.	◯ — ◯ Inhibitor arc
Agent	Active physical objects (system agents), humans, machines, or logical objects (software agents), capable of performing operations that eventually change the state of the system.	▮ Transition
Domain	Denote systems external to the system under consideration that may be collaborative or supportive. In the case of support systems, they can be associated with invariants or with a hypothesis, in the case of the collaborative system (an external objective to be satisfied), and in this case, it must contribute to the global objective of the system being modeled.	◯ Place External System
Entity	Represent passive and independent objects. Passive objects cannot perform operations; and are independent if they follow the object-oriented model with "behavioral completeness". Its attributes - whose admissible values must be specified - define the state of the system.	Token ◉ Place ▮ Transition

KAOS ELEMENTS	DESCRIPTION	PN CORRESPONDENCE
	Used to start or stop operations. Can be external or produced by operations (they are them made an output of the operation).	Token
	Used by different agents to enforce requirements. The operations can create objects, trigger state transitions and activate another series of operations by calling another event or operation.	
	Alternative connections (OR node) will be represented by independent connectors. The satisfaction of the objective will be achieved in a linear way once the requirement is fulfilled.	
	Each connection contributes to the satisfaction of the objective in an inclusive way (AND node).	
	Both goals can be achieved in any order without conflict, in a partial ordering.	
	Denotes the existence of a conflict between the objectives that prevents the satisfaction of both together.	
	Expectation will express the intention of an agent to fulfill an objective, having a certain level of priority in the system, but not being enough to satisfy the proposed objective.	
	Denotes the existence of obstacle or conditions prevent the satisfaction of a goal.	

A requirement is said to be "closed" when this triangular relationship Responsibility-Operationalization-Performance is established. The pattern is that an agent is responsible for a requirement; the agent performs an operation to satisfy this requirement; and there is a link, called operationalization, between the operation and the requirement. Therefore, requirement operationalization fills the gap between the problem description space (objects, requirements, and domain objects) and the solution description space (operations representing agents' behavior and objects interacting with those operations. KAOS can also model requirements for System of Systems (SoS) (MAIER, 1998), that is, a series of considerations must be analyzed to propose a correspondence between the elements of the KAOS and the Petri Nets, as shown in Table 1.

Once the requirements are modeled and all KAOS elements defined, the transfer process for PN can be carried out. Flowchart 20 shows the set of sequences necessary for a transfer process and is the base for the Python code provided in the Appendix F.

Different systems (from new designs or one already implemented) that collaboratively or supportively contribute to the system under consideration will be defined as a "Domain" element in KAOS, establishing a matching between them and the modeled system to satisfy the global objective. The "Domain" element is defined as a subsystem with requirements and definitions that, when transferred to a classic PN, will generate an external network to the global system. Future works can explore this transfer mechanism for HPN (Hierarchical Petri Net), exploiting their characteristics.

The proposed system has not been implemented (besides a prototype to match the process). Therefore, to control the elements generated during the different tests, an Excel template was used for requirements modeling (KAOS), generating and transferring a KML file into a PNML representation that was analyzed and simulated in the PIPE v4.3 tool.

3.2.5   Step 5: Requirements verification

Verification is an activity that involves analyzing a system to ensure that it meets functional and non-functional requirements (AHMAD; BELLOIR; BRUEL, 2015), confirming that the model obtained is consistent and complete (SOBEIH; VISWANATHAN; HOU, 2004). The dynamic analysis of processes aims to identify problems related to possible incompleteness, contradictory states, ambiguities, inconsistencies, and undesired conditions. This proposal analyzes the structural and behavioral properties of PN for the process dynamics concerning healthcare home services. PN-based models can evaluate parallel, concurrent, asynchronous, and non-deterministic systems. Thus, once the network is defined, conflicts and deadlocks can be verified by simulation or analysis of necessary conditions. For property analysis and PN simulation, we used the PIPE V4.3 tool.
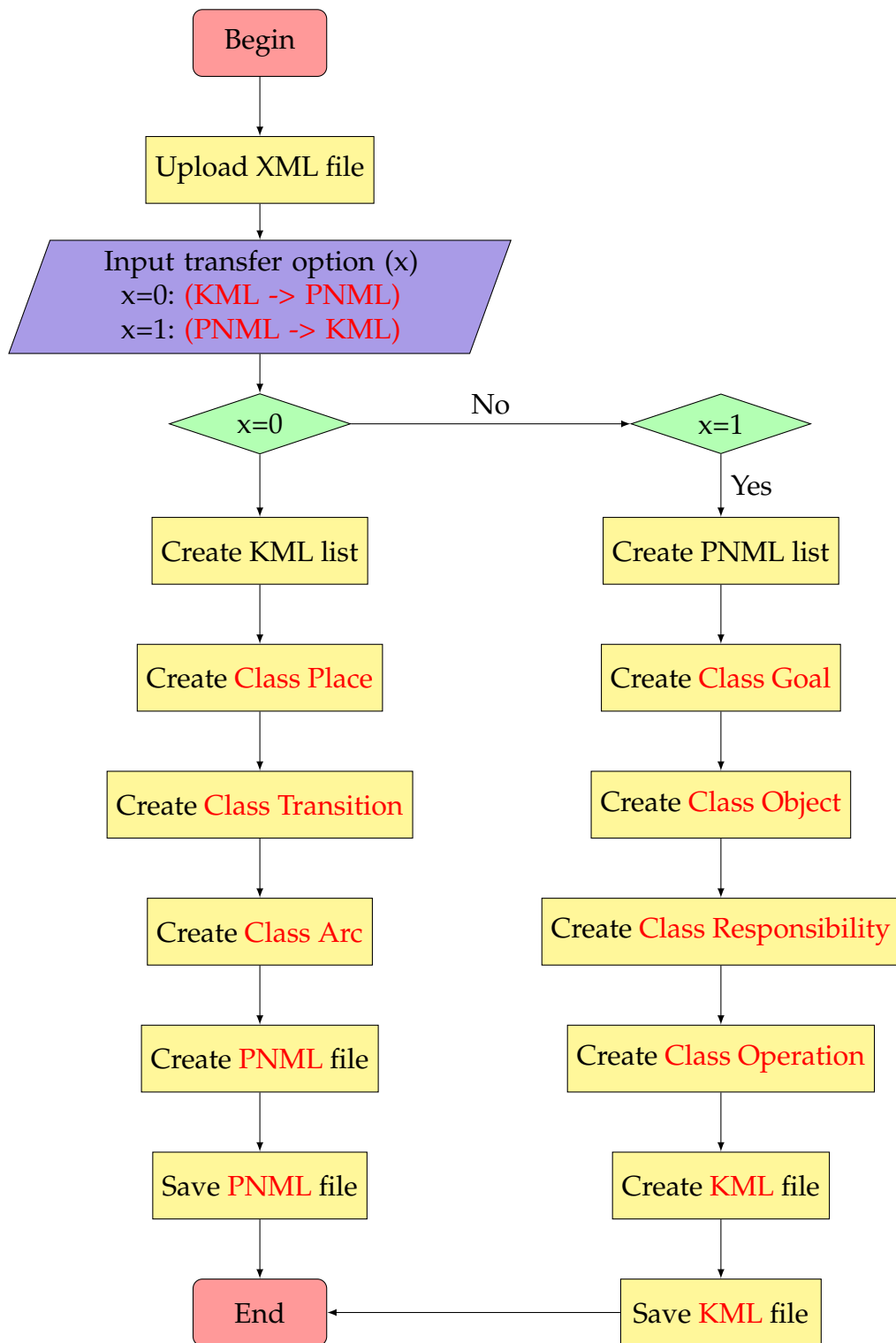
Figure 20 – Flowchart for KML <–> PNML transfer.

3.3   Product-service architecture (PSA)

Homecare and healthcare home systems will be treated as a product-service system, a network of services that can produce goods as a result of the process. Such a model is built as an analogy to manufacturing PSA.

A Smart Home system incorporates different components structured in a layered architecture. Each layer will respond to a system or process, has its function, and comes with its target mission or social goal. This multi-layered approach (SILVA *et al.*, 2021) separates the healthcare level from the automation level that is supposedly service-based. Figure 21 shows two layers of architecture where the bottom level (the domotic or smart home) covers the general automation process for the house while the top-level deals directly with the healthcare system.
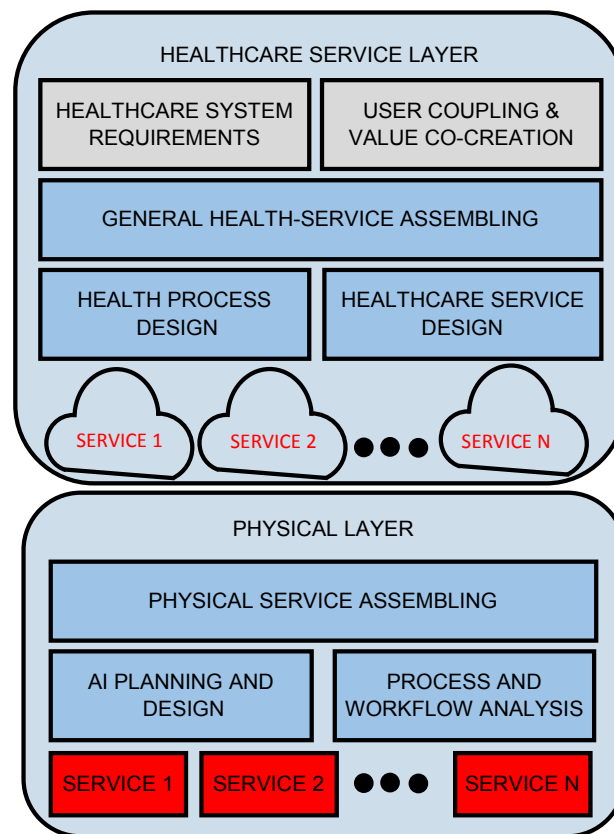
Figure 21 – PSA architecture for healthcare service.

The Physical Layer is in charge of the physical part of the system (equipment and homecare technology). Its service repository is used in workflow with its communication management. The planning activities compose the Physical Service Assembling, which is prepared to fit the Healthcare system's requirements.

The Healthcare Layer is responsible for interacting with the user and should meet specific physical and medical requirements inserted in a user coupling system. The Healthcare Layer relies on sound requirements collapsing automation, medical requirements, and user's value co-creation (collapsing healthcare and domotic interactions).

Both layers are still based on a PSA, as shown in Figures 22, 23. The different components of each layer that refer to the composition of the general architecture are shown in Figure 22.
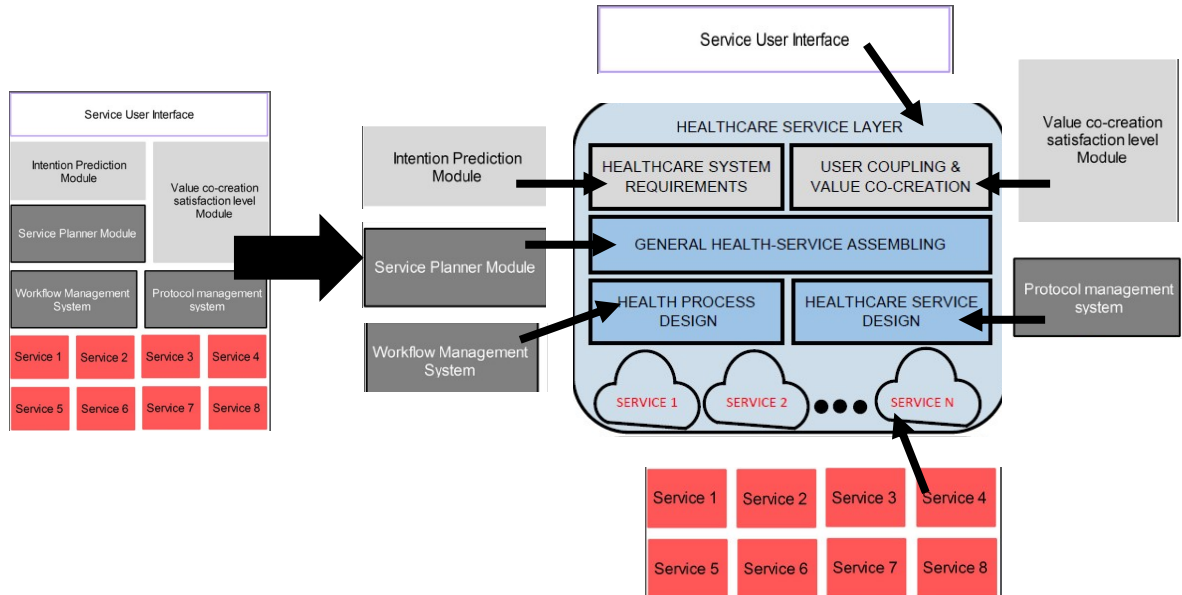
Figure 22 – Healthcare service layer.
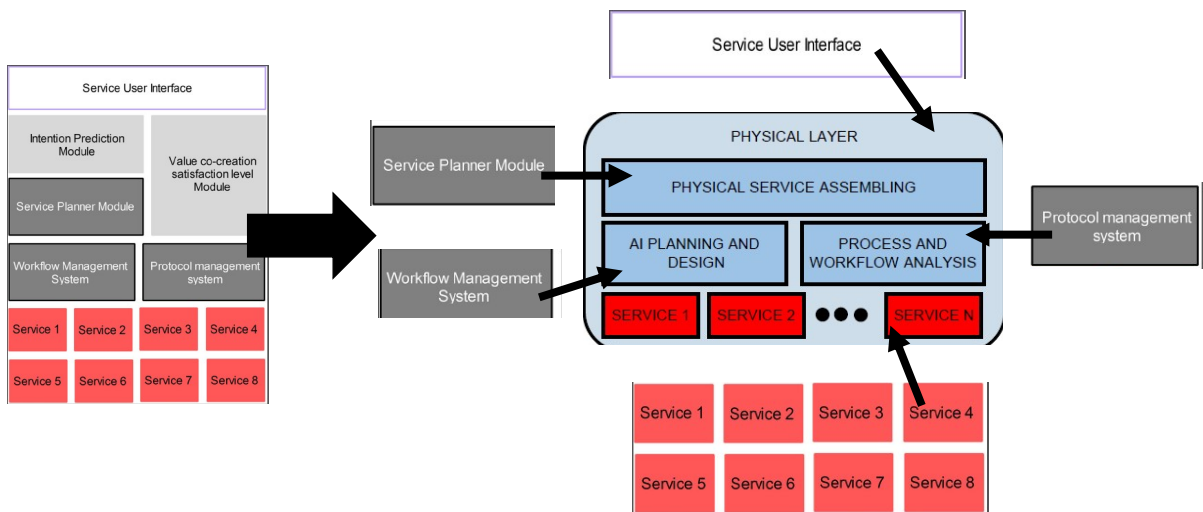
Figure 23 – Physical layer.

Therefore, the life cycle of the requirements is crucial for constructing components and processes to integrate the multilayer system.

Each process comprises activities that implement higher-level behaviors and can be synthesized by AI Planning. An Assembly level would coincide with the repository of services that belong to the Healthcare layer and the home automation services, called the Physical layer.

CHAPTER

4

CASE STUDY

This chapter illustrates the applicability of the proposal and possible results, using a case study that monitors vital signs and (elderly) user's movement, a collaboration between the D-LAB of the Department of Mechanical Engineering of the Polytechnic School of São Paulo University and the Laboratory of the Computational Intelligence Group Applied to Electrical Engineering (GICA EE) of the Federal University of Paraiba, (SILVA *et al.*, 2021).

4.1 Requirements cycle for healthcare service

This chapter present a case study where the proposed method is applied in a simple situation for monitoring old adults temporarily unattended.

4.1.1 Domain Data Collection.

This chapter will present a case study where the proposed method is applied in a simple situation for monitoring old adults temporarily unattended.

The selected case study could be part of a set of services eventually offered by condominiums directed to old adults. Automation is crucial to offer this community an affordable healthcare service at an affordable cost.

The application domain d [7] is composed of external agents and stakeholders (family, caregivers, nurses, and physicians) and by a domotic (automated) layer. For requirements modeling, doctors, hospitals, caregivers, and nurses are considered direct stakeholders. Insurance companies, home care agencies, pharmacies, and users (in the case of nursing homes) could also benefit from this model. Restrictions in the case study do not affect the method application conceptually, but reduce its size.

---

[7] The domain that surrounds and interacts more intensively with the system.

Generally, Ambient Assisted Living Systems (AALS) derives from the main idea of home automation, using distributed sensor systems to collect information related to the environment surrounding humans receiving the service. In response to this information, the system takes certain actions. It activates specific actuators to operate home devices (eventually belonging to the domotic layer), execute programmed functions, and interact with outside domains - in service of services mode. AALS homes are known as smart (intelligent), aware-house, and collaborative ambient intelligence. Homes with all these capabilities can assist older adults (or any patient) with services such as controlled medication, fall prevention, security features, and other telemedicine demands. Such systems generate a secure feeling for the patient while providing life quality (AL-SHAQI; MOURSHED; REZGUI, 2016).

Table 2 shows a summary of Assisting Smart Homes frameworks (similar to this case study), showing that this subject occupies many research and technology groups worldwide.

Table 2 – Application, sensor location and aims of recent AALS projects. Source (AL-SHAQI; MOURSHED; REZGUI, 2016)

Project	Origin	Application			Sensor		Alarms		
		1	2	3	4	5	6	7	8
AlarmNet Virginia	USA	-	-	-	✓	✓	✓	✓	-
Assisted Cognition Environment Washington	USA	✓	✓	-	✓	✓	✓	✓	✓
AWARE Georgia	USA	✓	✓	-	✓	✓	✓	✓	✓
CASAS	Washington, USA	✓	✓	-	✓	✓	✓	✓	✓
Casattenta	Bologna, Italy	✓	✓	✓	✓	✓	✓	✓	✓
GatorTech Smart House	Florida, USA	✓	-	✓	✓	-	✓	-	-
GeorgiaTech Aware Smart Home	Georgia, USA	✓	✓	✓	✓	✓	✓	✓	-
Gerontological Smart Home Environment	Paris, France	✓	✓	✓	✓	✓	✓	✓	-
I-LivingTM	Illinois, USA	✓	✓	-	✓	-	✓	-	-
MavHome	Texas, USA	✓	✓	-	✓	-	✓	-	-
ORCATECH	Oregon, USA	✓	✓	✓	✓	-	✓	✓	✓
SOPRANO	Patras, Greece	✓	✓	✓	✓	-	✓	✓	✓
TAFETA	Ottawa, Canada	✓	✓	-	✓	-	✓	✓	-
WellAWARE	Virginia, USA	✓	✓	✓	✓	-	✓	✓	✓

Project	Origin	Application			Sensor		Alarms		
		1	2	3	4	5	6	7	8
CareWatch	Scotland, UK	✓	-	✓	-	-	-	-	-
TeleCARE	Scotland, UK	✓	✓	✓	✓	-	✓	✓	-
CAALYX	Madrid, Spain	✓	✓	✓	✓	-	✓	✓	-

1: Safety 2: Health and wellbeing 3: Social interaction 4: Physically fixed
5: Wearable 6: Environmental 7: Health 8: Cognitive

4.1.2 "System As-Is" requirements specification.

The information collected from the home care domain is analyzed and modeled into "System As-Is" (including the home automation), resuming expectations (or a legacy system). (SILVA *et al.*, 2021) proposes a *legacy system* for this work, where the main goal is to monitor the night sleep of old adults. This primary goal should become a service implemented to compose a cloud service repository with other services in a distributed approach, as shown in Figure 21.

Figure 24 reproduces the requirements for the *legacy system*. The "System As-Is" was modeled to represent a requirement base, using KAOS hierarchical approach.

Once the primary goal is established, *Monitoring elderly night sleep*, we must look for supporting *sub-goals*: monitoring the sleep, detecting awaking, Monitoring waking activities. As the refinement model evolves, the inclusion of services and equipment already developed can be detected for reuse (included as subgoals in the KAOS diagram). For instance, to monitor sleep, there are two possibilities: sensors installed in the bed, several smart house projects already have that or, if the user suffers from apnea, a Continuous Positive Airway Pressure (CPAP). A CPAP tool is a physical product-service system connected to the wireless network that sends data to a (cloud) service that analyses sleep and its possible anomalies. If the user awakes, another user-coupling process will start. First, the system call movement detection (from a domotic system) to see if the patient is about to leave the bed. If so, another physical service (still from domotics) is called to turn on the lights in the bedroom. Presence detection (generally used for security) checks if the user is heading to the bathroom. In that case, it turns on the bathroom lights. A healthcare layer service should monitor patient movements to detect falls or stumble. In such cases, an alarm signal is sent to a caregiver - a decision taken by the AI system belonging to the healthcare layer) (SILVA *et al.*, 2021).

4.1.3 "System-To-Be" requirements specification.

The "System-As-Is" goal model is the starting point to building the future system, initially collapsing the functional and non-functional goals. New requirements will emerge from different classes of stakeholders to form a new (automated) system that
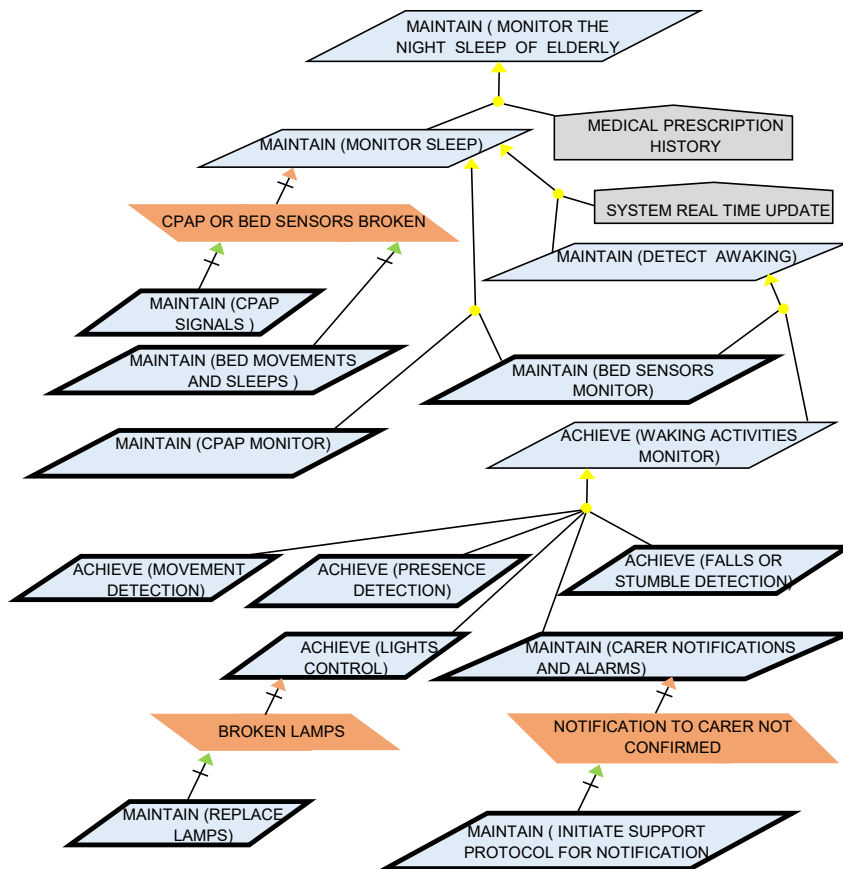
Figure 24 – Requirements for Monitoring elderly night sleep ("System As-Is"). Source: (SILVA *et al.*, 2021).

replaces the predecessor. In addition to emerging requirements foreseen in modeling the "System-As-Is," expectations, obstacles, or limitations will lead to new requirements. Following the System Design approach, we must first identify the problem *P* and its relation with its environment (the domain *d*). Frequently, a wide range of wearables is proposed for old adults' healthcare (LIN *et al.*, 2017), (DEEN, 2015) eventually based on artificial intelligence (AI). Those wearables can gather and analyze patient activities and health status information and identify and report anomalies. Depending on the device, it is also possible to add new functions. However, all data must be consolidated into a general orchestrator to ensure proper healthcare action.

Therefore, to model a "System-To-Be" with new functionalities and a higher level of completeness and complexity, new requirements arose from the "System As-Is" related to:

- Automated emergency calls: Some smart home solutions (Aware, CASAS, Gerontological Smart Home Environment, SOPRANO) monitor the home environment

and the patient physiological parameters and should generate alerts in case of emergencies.

- Automated activity and fall detection: Smart homes (AlarmNet Virginia, Assisted Cognition Environment Washington, MIT House-n, ORCATECH, CareWatch) must distinguish between normal and abnormal activities. They restrict the user from residing within a specific area. Systems using video-based or motion sensors such as accelerometers, gyroscopes, and magnetometers can discriminate in these situations.

- Monitoring vital signs: Vital signs, including heart rate (HR), body temperature (BT), respiration rate (RR), and blood pressure (BP), are the parameters that medical professionals routinely monitor to get a good overview of the patient's health. Some projects with these functionalities are I-LivingTM, ORCATECH, SISARL, Shimmer Platform, and Smart Medical Home.

- Reminding system: Memory and cognitive functions in older adults gradually decline with age, leaving the older people with severe memory loss and dementia, which cause delays in daily activities and sometimes become dangerous. Forgetting regular medication or ingesting more than prescribed doses are good examples. Smart homes with a reminder service (AlarmNet Virginia, AWARE Georgia, MavHome, SOPRANO, TAFETA) can send alerts and information to users, families, caregivers, and physicians.

Figure 25 shows the correspondent KAOS diagram for the new system. In the proposed model, the main objective (*Monitor elderly night sleep and vital signs*) and its refinements are identified and refined to a more elementary level of requirements or domains (corresponding to the home automation layer). Expectations - such as *Patient Confirmation, Caregiver Confirmation, Family Confirmation, Physician Confirmation* - are fulfilled in the system by agents, establishing a responsibility link between them. The interaction between the system and agents (end users) would be the basis for creating service values. For the target requirements (*Send Patient Alert, Sent Family Alert, Sent Caregiver Alert, Sent Physician Alert*) to be achieved, a triggering event (*Notification*) is expected to launch a corresponding operation (*Sent Notification*). This operation is executed by the agent (*Notification system*) using specific system resources to bring it to the desired state. To achieve the *Reminder* objective, it is expected a patient's notification and a corresponding notifications to at least one of the family members, to the caregiver, or to the physician be confirmed, preventing the patient lack of action.
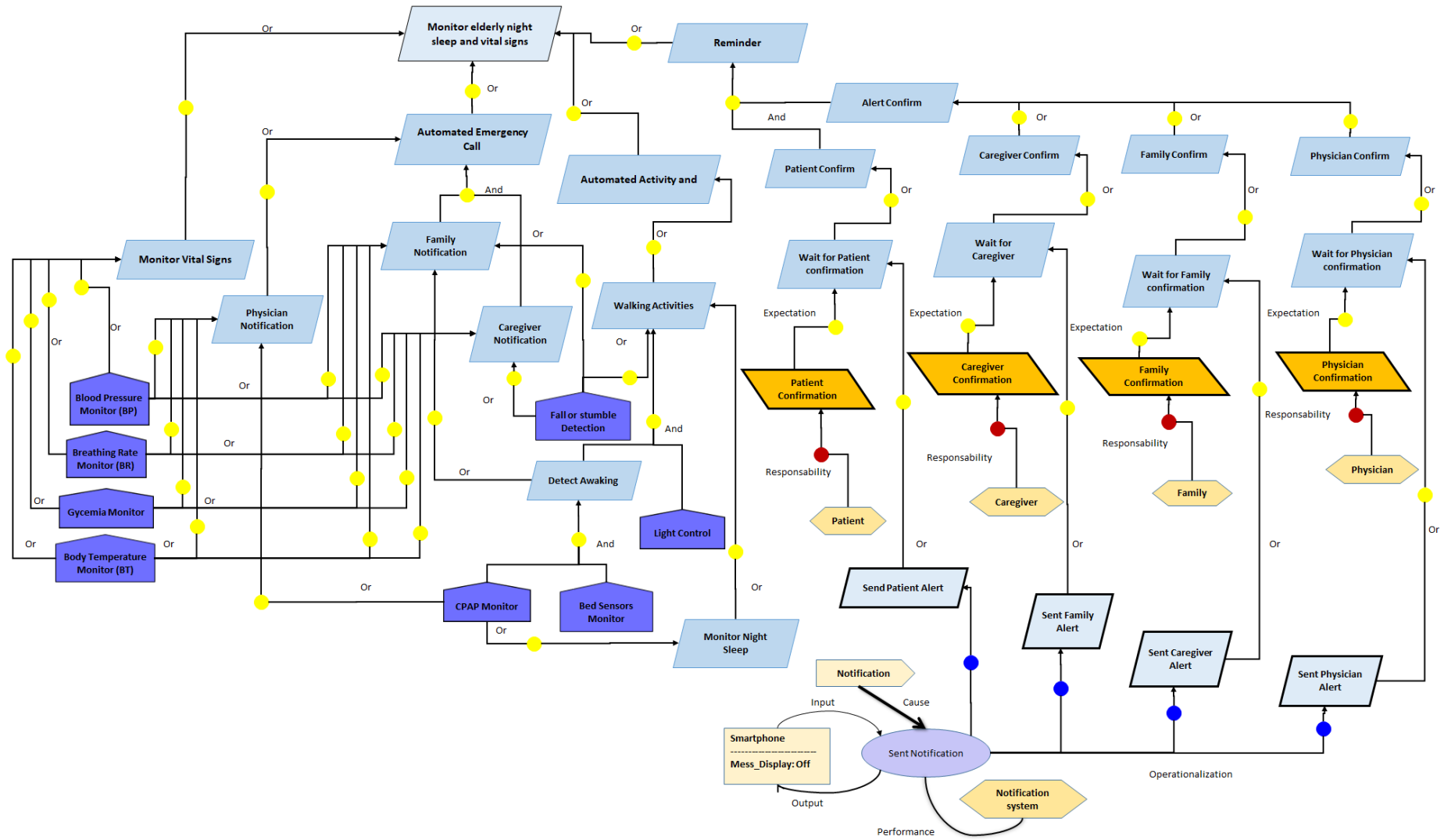
Figure 25 – Requirements for Monitor elderly night sleep and vital signs ("System To-Be").

Figure 26 – Petri net for Monitor elderly night sleep and vital signs ("System To-Be").

The corresponding KML file generated for *Monitor elderly night sleep and vital signs* is shown in the Appendix D. Figure 26 shows the Petri net synthesized from modeling the requirements of the global system, observing the transfer of KAOS diagrams to Petri nets, the resulting PNML file is shown in the Appendix E.

4.1.3.1   Matching Layer Requirements

In this case study, the matching between the layers was simplified, modeling the domotic services as a *"Domain"*, shown in Figure 27. Intelligent systems associated with telemedicine are associated with further work and do not enter into the scope of this dissertation.
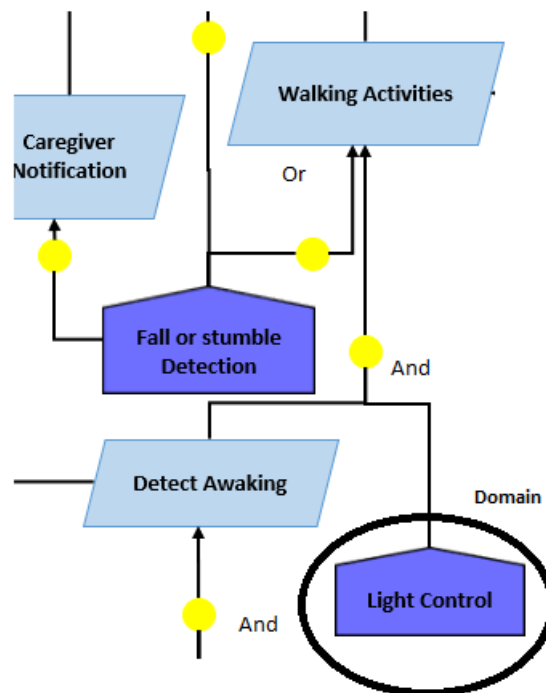
Figure 27 – Global system section related to the lighting control domain.

The service (*Light Control*) is modeled as *"Domain"* and corresponds to the physical layer associated with home automation. This service has a set of objectives and requirements, shown in Figure 28, each with its purpose but contributing to the global objective of the system. Domotic sensors and actuators are used to detect movement and presence to guarantee that the lights turn on in the place where the user is, or the *Detect Awaking* service used to launch (*Walking Activities Detect*), belonging to the healthcare layer. The *"Domain"* matching can be replaced by sending a message or activating a domotic control signal, as shown in (SILVA *et al.*, 2021). Therefore this does not change the life cycle presented here.

Details about capturing (in KML) the goal and requirements for a *"Light Control"* service is shows in Appendix G.

Figure 29 shows the Petri Net[8] generated for *"Light Control"* service requirements. The corresponding PNML code is shown in Appendix H.
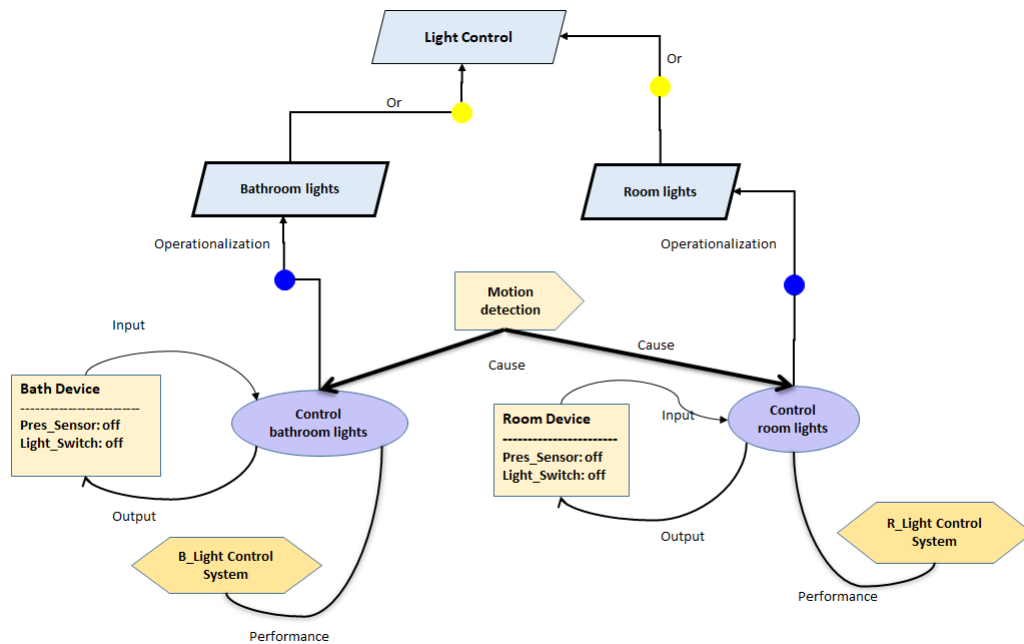
Figure 28 – KAOS diagram corresponding to light control.

4.1.4 Requirements verification.

The formal verification of requirements is carried out through the analysis of the dynamics of the Petri net, Figure 29, to support the enhancement of the requirements cycle. For the analysis of requirements, the structural and behavioral properties are analyzed, we will show a place invariant that meets the initial and dynamic requirements (requirements that should be preserved either in the requirements analysis cycle) for this process(SALMON; FOYO; SILVA, 2014).

The equation 4.1 for the Place Invariants (P) shows that positive P-Invariants cover the network. Therefore it is limited (the sum of the place tokens is equal to one). Also, it could be inferred that no matter the initial marking of the network, there will always be a safe place marked for this process, being able to define the control sequence for the lights at all times.

---

[8] Notice that this net is cyclic, as expected from a process that has an activation state (the initial state) and runs from there, returning to the initial state.
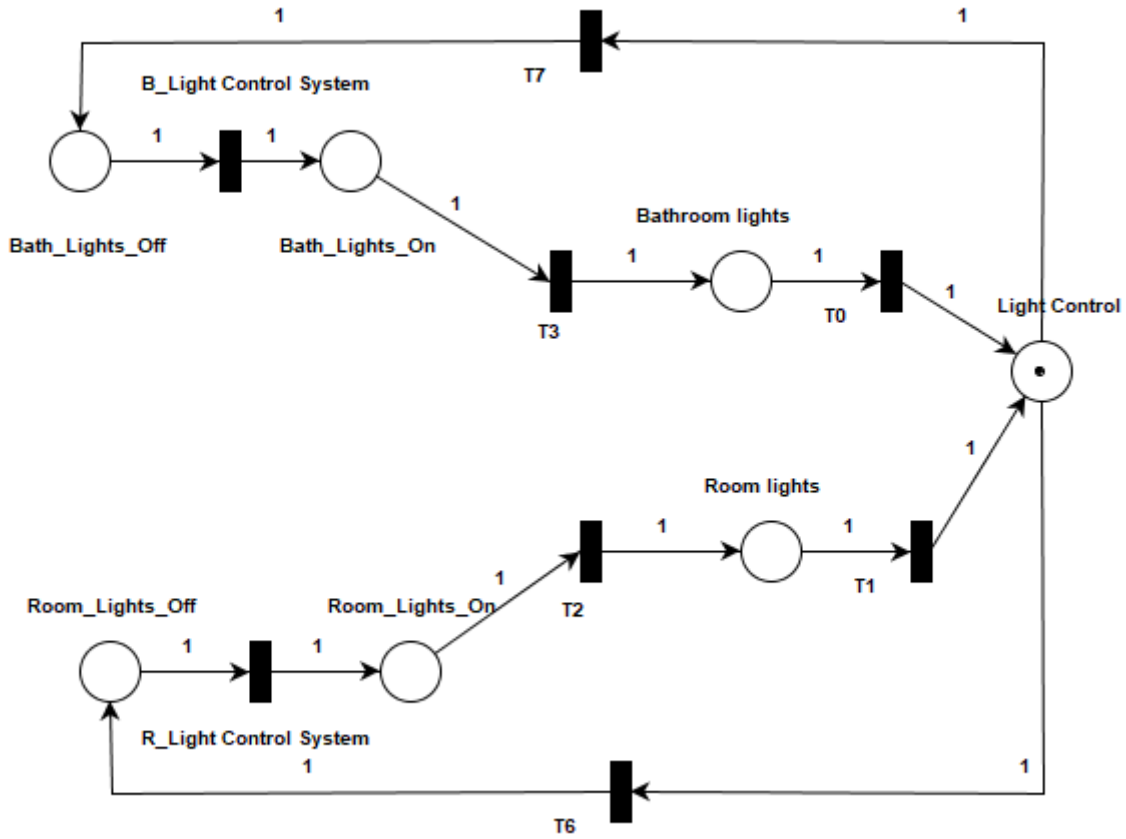
Figure 29 – Petri Net corresponding to light control.
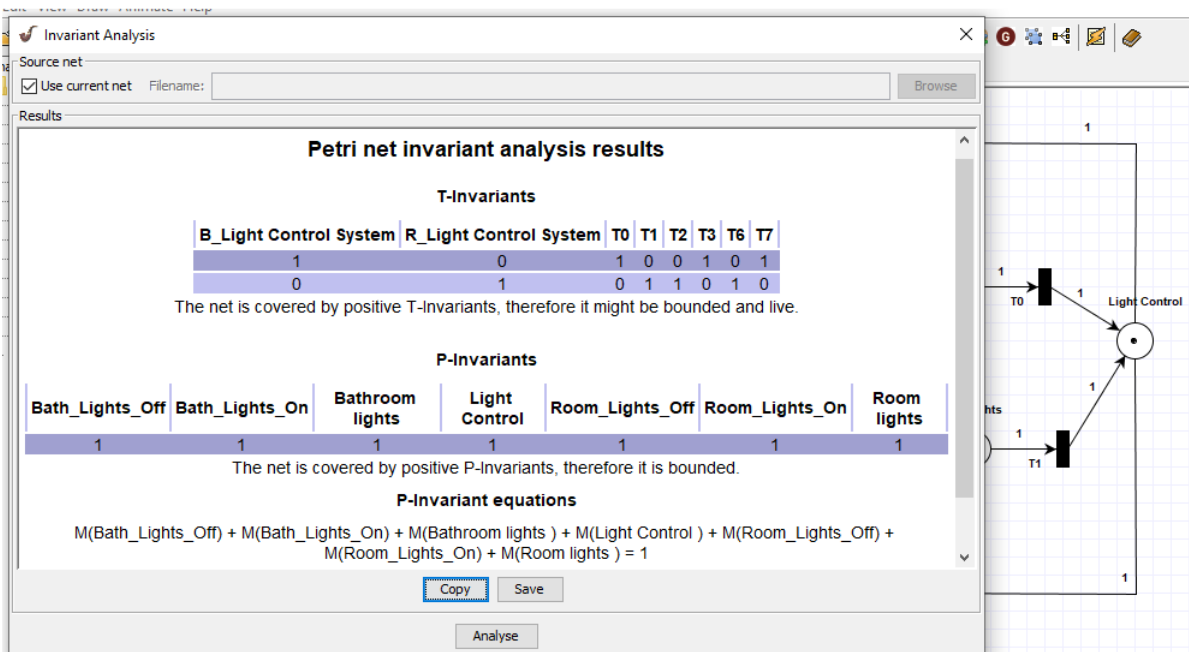
Figure 30 – Analysis of structural properties of the Petri net. Source: PIPE V4.3

$$M(Bath\_Lights\_Off) + M(Bath\_Lights\_On) + M(Bathroom\_lights) + M(Light\_Control) +$$
$$M(Room\_Lights\_Off) + M(Room\_Lights\_On) + M(Room\_lights) = 1$$

$$(4.1)$$

Considering the analysis related to the reachability tree (Figure 31) and the space of states (Figure 32) generated by the Petri Net, it can be concluded that all marks can be reached from the start mark. Indicating that the network adequately represents the modeled process.
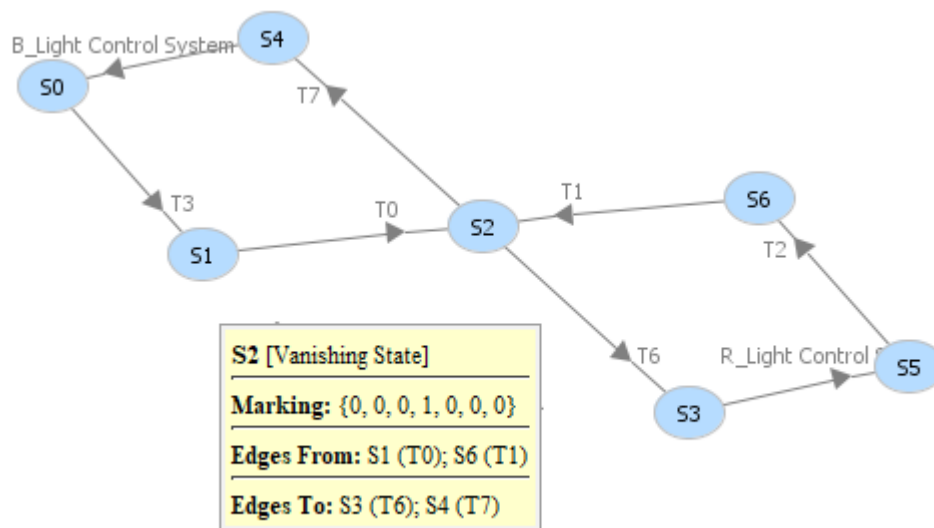
Figure 31 – Reachability tree. Source: PIPE v4.3.0
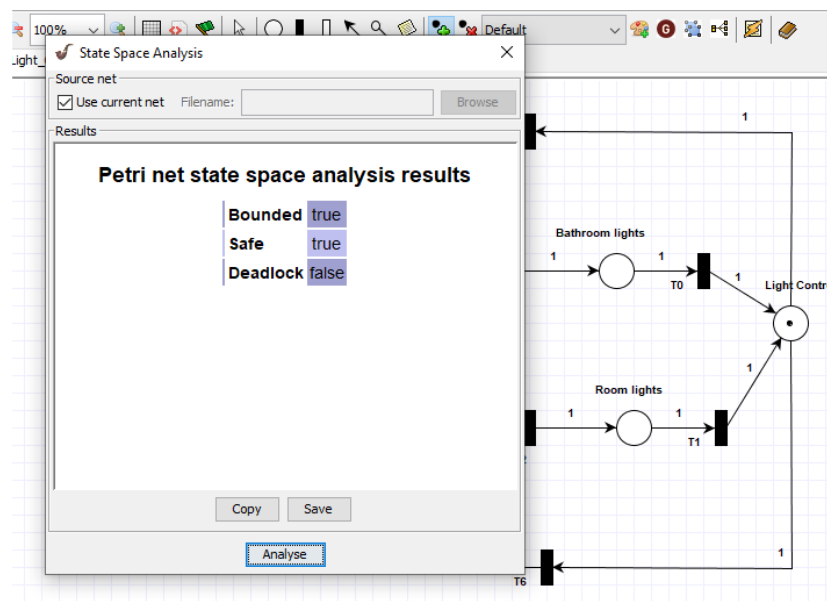
Figure 32 – Analysis of dynamic properties of the Petri net. Source: PIPE V4.3

We can also derived that:

1. The Petri net obtained is alive and free of deadlocks (result obtained by simulation);

2. The network is limited, which implies that the system is closed and controllable;

3. The network is reversible since it is always possible to return to the initial state.

4.2   Product-service architecture (PSA)

The architecture proposal for this case study is described below:
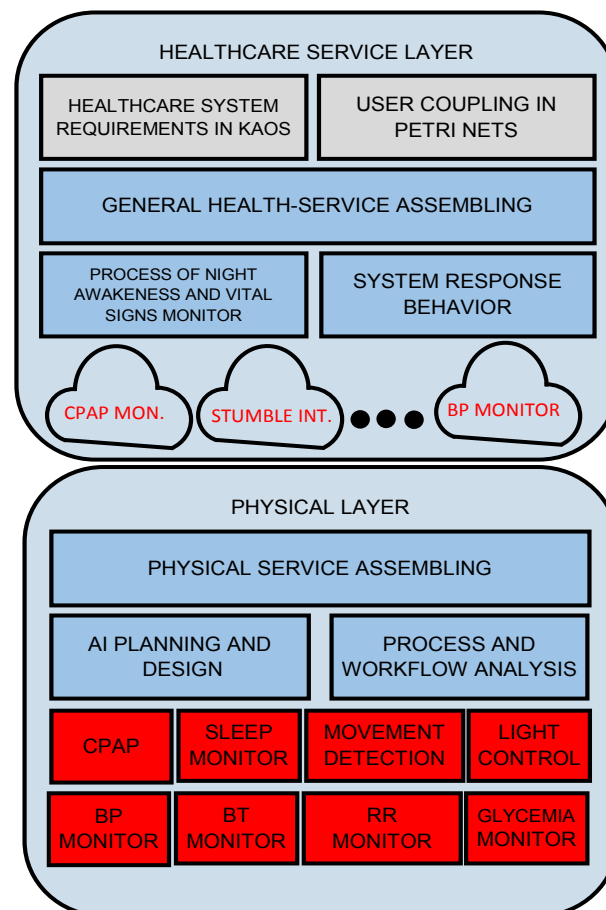
Figure 33 – PSA for Monitoring the night sleep and vital signs of elderly people.

Figure 33 reproduces the schema of Figure 21 for a Product-service Architecture proposed by D-Lab (de S. Dutra; SILVA, 2016). Resources, services, and equipment are combined to satisfy a more abstract objective. Available cloud services will compose the new service.

As a distinguishing characteristic of services, the main system is divided into two main goals:

- To satisfy the objects of the healthcare system modeled by KAOS diagrams and verified by Petri Nets;

- specifies the user-journey or value co-creation for the coupling with the user, also formalized in Petri Nets.

Generically the main Healthcare Assembling of functions and (cloud-based) sub-services are divided into two blocks: the awareness block - with the services that perform the night awareness and vital signs monitoring; and the communication system, which is responsible for the alarms and user feedback.

Besides using its services (CPAP monitoring, Stumble and fall detecting, and others), the whole system relies on the domotic system, configuring a two-layer system. This supporting layer can have a planning model for activities programmed to assist the user, formalized by workflows in Petri Nets. AI supports the planning approach. In this case study, we abstract all these functions and associate the supporting layer with a "domain" in the KAOS diagram, capable of changing signs and messages with the primary healthcare system.

Notice that the systemic design approach adopted here is object-oriented, which allows some flexibility to assume that the supporting layer and its internal assembling of services are just encapsulated elements with which we can exchange signs and messages.

PSA is a proposition of D-Lab, but today there is a more generic concept spread worldwide: the product-service systems (PSS), which stress the systematic approach more generically. PSA would be a special case of PSS. However, that inserts the current proposal into the most recent proposals for the design of service systems used in manufacturing and automation in general.

CONCLUSION AND FURTHER WORK

5.1   Conclusion

This work proposed a layered development cycle for modeling and analyzing the early stages of requirements and their suitability for healthcare in smart homes. The layered approach has the advantage of using legacy domotic systems in the new design, reducing dependency and improving flexibility. Such advantages come from using Goal-Oriented methods to model requirements and its further formalization in Petri Net formalism, used for modeling and verification. For matching goal-oriented requirements with the Petri nets - a formal representation for automated processes - it was necessary to develop a KML (KAOS Markup Language) representation and an algorithm to transfer that to PNML (Petri Net Markup Language). The method was adapted to fit the PSA architecture proposed by the D-Lab in 2016, which was also revised.

A case study was presented where the two layers system integrates: the physical home automation and the service system directed to intensive healthcare. Here we supposed the domotic system was already designed, configuring a legacy system. This assumption constitutes an ideal situation; however, a simultaneous design could also be performed, with the same problems that emerge when we have to automate domes being built simultaneously.

Methodologically, the proposal includes a model-based requirements life cycle (Model-Based Requirements Engineering (MBRE) oriented by objectives (GORE) emphasizing communication and coupling with the end-user and the proposal of a service architecture for a multilayer system of healthcare services in smart homes.

KAOS can be considered a promising mechanism for Requirements Engineering in healthcare systems modeling since it allows the proper adaptation of healthcare to

different backgrounds and automated homes. In the extreme, it could also be applied and adapted to a home without automation. That could be an essential issue in diversifying public home care, making it more accessible to be distributed and used with telemedicine in public health systems.

As a reference, MBRE (Model-Based Requirements Engineering) (SILVA *et al.*, 2021) emphasizes the formalization of the dynamics of the requirements models in each step of development and, therefore, a formal analysis to ensure consistency and completeness. The details of the formal analysis are developed based on structural and behavior analysis of workflow based on Petri Nets. Remarkably, the invariant analysis will be essential to verify requirements and detect those qualified as *dynamic*, which should be preserved even in the presence of emergent changes in the project before it reaches a cycle. Although the contribution of this work is not the proposition of MBRE, it contributed to reinforcing the use of invariants in the requirements development.

A Product-Service architecture (PSA) was the reference to the healthcare layer, understanding that health assistance is a direct service delivered to personalized users, which demands capillarity, on one side and convergence, on the other side, to allow the management of a health system.

Future works could explore using the Hierarchical Petri Nets (HPN) hierarchy to encapsulate all the services involved in the global system. Also the implementation of the KML <–>PNML transfer proposal, Figure 18, using cloud-hosted services.

BIBLIOGRAPHY

AHMAD, M.; BELLOIR, N.; BRUEL, J. M. Modeling and verification of Functional and Non-Functional Requirements of ambient Self-Adaptive Systems. **Journal of Systems and Software**, v. 107, n. May, p. 50–70, 2015. ISSN 01641212. Cited on page 70.

AL-SHAQI, R.; MOURSHED, M.; REZGUI, Y. Progress in ambient assisted systems for independent living by the elderly. **SpringerPlus**, v. 5, n. 1, p. 4–20, 2016. ISSN 21931801. Cited 9 times on pages 15, 40, 42, 46, 49, 50, 51, 64, and 76.

ALAM, M. R.; REAZ, M. B. I.; ALI, M. A. M. A review of smart homes - Past, present, and future. **IEEE Transactions on Systems, Man and Cybernetics Part C: Applications and Reviews**, v. 42, n. 6, p. 1190–1203, 2012. ISSN 10946977. Cited 3 times on pages 22, 39, and 64.

ALQARNI, M.; JANICKI, R. Interval semantics for Petri nets with inhibitor arcs. **Theoretical Computer Science**, Elsevier B.V., v. 727, p. 1–23, 2018. ISSN 03043975. Disponível em: <https://doi.org/10.1016/j.tcs.2018.03.003>. Cited on page 67.

BAL, M.; SHEN, W.; HAO, Q.; XUE, H. Collaborative Smart Home technologies for senior independent living: A review. **Proceedings of the 2011 15th International Conference on Computer Supported Cooperative Work in Design, CSCWD 2011**, IEEE, p. 481–488, 2011. Cited 11 times on pages 13, 40, 41, 44, 45, 46, 47, 49, 51, 52, and 53.

BENNACEUR, A.; TUN, T. T.; YU, Y.; NUSEIBEH, B. Requirements engineering. In: ____. **Handbook of Software Engineering**. Springer International Publishing, 2019. p. 51–92. ISBN 978-3-030-00262-6. Disponível em: <https://doi.org/10.1007/978-3-030-00262-6_2>. Cited 3 times on pages 13, 27, and 28.

BKCASE Editorial Board. Guide to the Systems Engineering Body of Knowledge. **Guide to the Systems Engineering Body of Knowledge (SEBoK)**, n. October, p. 945, 2021. Disponível em: <http://g2sebok.incose.org/app/mss/menu/index.cfm>. Cited 2 times on pages 62 and 63.

BURNS, A.; GREENE, B. R.; MCGRATH, M. J.; O'SHEA, T. J.; KURIS, B.; AYER, S. M.; STROIESCU, F.; CIONCA, V. SHIMMERTM - A wireless sensor platform for noninvasive biomedical research. **IEEE Sensors Journal**, v. 10, n. 9, p. 1527–1534, 2010. ISSN 1530437X. Cited on page 52.

BDIC, C.; BREZOVAN, M.; BDIC, A. An overview of smart home environments: Architectures, technologies and applications. **CEUR Workshop Proceedings**, v. 1036, n. i, p. 78–85, 2013. ISSN 16130073. Cited on page 22.

CHAN, M.; ESTÈVE, D.; ESCRIBA, C.; CAMPO, E. A review of smart homes-Present state and future challenges. **Computer Methods and Programs in Biomedicine**, v. 91, n. 1, p. 55–81, 2008. ISSN 01692607. Cited 3 times on pages 22, 39, and 64.

CHIABRANDO, F.; DONATO, V.; TURCO, M. L.; SANTAGATI, C. **Cultural Heritage Documentation, Analysis and Management Using Building Information Modelling: State of the Art and Perspectives**. Cham: Springer International Publishing, 2018. 181–202 p. ISBN 978-3-319-68646-2. Disponível em: <https://doi.org/10.1007/978-3-319-68646-2_8>. Cited on page 22.

COOK, D. J.; KRISHNAN, N. C.; RASHIDI, P. Activity discovery and activity recognition: A new partnership. **IEEE Transactions on Cybernetics**, v. 43, n. 3, p. 820–828, 2013. ISSN 21682267. Cited 3 times on pages 13, 42, and 43.

COOK, D. J.; YOUNGBLOOD, M.; HEIERMAN, E. O.; GOPALRATNAM, K.; RAO, S.; LITVIN, A.; KHAWAJA, F. MavHome: An agent-based smart home. **Proceedings of the 1st IEEE International Conference on Pervasive Computing and Communications, PerCom 2003**, n. April, p. 521–524, 2003. Cited 2 times on pages 13 and 48.

CREAN, C.; MCGEOUGE, C.; O'KENNEDY, R. 11 - wearable biosensors for medical applications. In: HIGSON, S. (Ed.). **Biosensors for Medical Applications**. Woodhead Publishing, 2012, (Woodhead Publishing Series in Biomaterials). p. 301–330. ISBN 978-1-84569-935-2. Disponível em: <https://www.sciencedirect.com/science/article/pii/B9781845699352500115>. Cited on page 40.

DAIMI, K.; LI, L.; LU, X.; EL-NAZEER, N. Requirements engineering for home health care software systems. In: **Software Engineering Research and Practice**. [S.l.: s.n.], 2010. Cited 4 times on pages 23, 37, 38, and 64.

DAVIDRAJUH, R. Developing a new petri net tool for simulation of discrete event systems. **Proceedings - 2nd Asia International Conference on Modelling and Simulation, AMS 2008**, p. 861–866, 2008. Cited on page 58.

de S. Dutra, D.; SILVA, J. R. Product-Service Architecture (PSA): toward a Service Engineering perspective in Industry 4.0. **IFAC-PapersOnLine**, v. 49, n. 31, p. 91–96, 2016. ISSN 24058963. Cited 2 times on pages 56 and 86.

DEEN, M. J. Information and communications technologies for elderly ubiquitous healthcare in a smart home. **Personal and Ubiquitous Computing**, Springer London, v. 19, n. 3, p. 573–599, 2015. ISSN 16174909. Cited on page 78.

DISHMAN, E. Inventing Wellness Systems for Aging in Place. **Computer**, v. 37, n. 5, p. 34–41, 2004. ISSN 00189162. Cited on page 52.

FARELLA, E.; FALAVIGNA, M.; RICC, B. Aware and smart environments: The Casattenta project. **Microelectronics Journal**, v. 41, n. 11, p. 697–702, 2010. ISSN 00262692. Cited 3 times on pages 13, 43, and 44.

GONZÁLEZ, P. M.; SALMON, A. O.; SILVA, J. R. Requirements Analysis of Automated Projects Using Uml / Petri Nets. **Brazilian Congres on Mechanical Engineering**, v. 5, p. 761–770, 2011. Cited on page 66.

GUTIERREZ, E. V.; GUTIERREZ, V.; VIDAL, C. J. Home health care logistics management: Framework and research perspectives. **International Journal of Industrial Engineering and Management**, v. 4, n. 3, p. 173–182, 2013. ISSN 22172661. Cited on page 23.

HASAN, M.; BISWAS, P.; BILASH, M. T. I.; DIPTO, M. A. Z. Smart home systems: Overview and comparative analysis. **Proceedings - 2018 4th IEEE International Conference on Research in Computational Intelligence and Communication Networks, ICRCICN 2018**, n. November, p. 264–268, 2018. Cited 7 times on pages 13, 40, 43, 44, 45, 46, and 64.

HORKOFF, J.; AYDEMIR, F. B.; CARDOSO, E.; LI, T.; MATÉ, A.; PAJA, E.; SALNITRI, M.; MYLOPOULOS, J.; GIORGINI, P. Goal-Oriented Requirements Engineering: A Systematic Literature Map. **Proceedings - 2016 IEEE 24th International Requirements Engineering Conference, RE 2016**, p. 106–115, 2016. Cited on page 30.

HORKOFF, J.; AYDEMIR, F. B.; CARDOSO, E.; LI, T.; MATÉ, A.; PAJA, E.; SALNITRI, M.; PIRAS, L.; MYLOPOULOS, J.; GIORGINI, P. Goal-oriented requirements engineering: an extended systematic mapping study. **Requirements Engineering**, v. 24, n. 2, p. 133–160, 2019. ISSN 1432010X. Cited on page 30.

KAUTZ, H.; FOX, D.; ETZIONI, O.; BORRIELLA, G.; ARNSTEIN, L. An Overview of the Assisted Cognition Project. **AAAI Workshop on Automation as Caregiver: The Role of Intelligent Technology in Elder Care**, n. Lawton, p. 60–65, 2000. Cited 2 times on pages 13 and 41.

KIDD, C. D.; ORR, R.; ABOWD, G. D.; ATKESON, C. G.; ESSA, I. A.; MACINTYRE, B.; MYNATT, E.; STARNER, T. E.; NEWSTETTER, W. The aware home: A living laboratory for ubiquitous computing research. **Lecture Notes in Computer Science (including subseries Lecture Notes in Artificial Intelligence and Lecture Notes in Bioinformatics)**, v. 1670, n. January, p. 191–198, 1999. ISSN 16113349. Cited on page 42.

KIENTZ, J. A.; PATEL, S. N.; JONES, B.; PRICE, E.; MYNATT, E. D.; ABOWD, G. D. The Georgia tech aware home. **Conference on Human Factors in Computing Systems - Proceedings**, p. 3675–3680, 2008. Cited on page 44.

LEE, H.; SHARDA, B.; BANERJEE, A. Representation and simulation of stochastic petrinet models using xPNML. **Proceedings - Winter Simulation Conference**, p. 1063–1071, 2007. ISSN 08917736. Cited on page 58.

LIN, M.-h.; YUAN, W.-l.; HUANG, T.-c.; ZHANG, H.-f.; MAI, J.-t.; WANG, J.-f. Clinical effectiveness of telemedicine for chronic heart failure: a systematic review and meta-analysis. **Journal of Investigative Medicine**, BMJ Publishing Group Limited, v. 65, n. 5, p. 899–911, 2017. ISSN 1081-5589. Disponível em: <https://jim.bmj.com/content/65/5/899>. Cited on page 78.

MA, B. X.; XU, Y. L. Integrating PNML with OWL for petri nets. **Proceedings - 2009 2nd IEEE International Conference on Computer Science and Information Technology, ICCSIT 2009**, IEEE, p. 228–230, 2009. Cited on page 58.

MAIER, M. W. Architecting principles for systems-of-systems. **Systems Engineering**, v. 1, n. 4, p. 267–284, 1998. ISSN 15206858. Cited on page 70.

MARTIN, J. N. 3.1.2 The Seven Samurai of Systems Martin, J. N. (2004) '3.1.2 The Seven Samurai of Systems Engineering: Dealing with the Complexity of 7 Interrelated Systems', INCOSE International Symposium, 14(1), pp. 459–470. doi: 10.1002/j.2334-5837.2004.tb00509.x.En. **INCOSE International Symposium**, v. 14, n. 1, p. 459–470,

2004. ISSN 23345837. Disponível em: <http://doi.wiley.com/10.1002/j.2334-5837.2004.tb00509.x>. Cited on page 64.

MARTINS, F. d. O. C.; ALMEIDA, M. F. L. de; CALILI, R. F. Design thinking aplicado a projetos de casas inteligentes: modelo para geração e seleção de concepções baseadas em soluções tecnológicas inovadoras. **XVII Congreso Latino-Iberoamericano de Gestión Tecnológica**, p. 1–15, 2017. Cited on page 22.

MATOUSSI, A.; PETIT, D. Bridging the gap between KAOS requirements models and B specifications. **Complexity**, n. 33, 2009. Cited on page 32.

MCGEE-LENNON, M. R. Requirements engineering for home care technology. **Conference on Human Factors in Computing Systems - Proceedings**, p. 1439–1442, 2008. Cited 3 times on pages 38, 64, and 65.

MCGEE-LENNON, M. R.; GRAY, P. D. Including stakeholders in the design of home care systems: Identification and categorisation of complex user requirements. In: **in Proc. Include**. [S.l.: s.n.], 2007. Cited 2 times on pages 37 and 64.

MEZO, B. M.; CHAPARRO, T. S.; HERAS, A. D. Main characteristics of companies using service oriented architecture (soa) and of their operation context. **JISTEM - Journal of Information Systems and Technology Management (Online)**, v. 5, n. 2, p. 269–304, Jan. 2008. Disponível em: <https://www.revistas.usp.br/jistem/article/view/12806>. Cited on page 54.

MÜLLER, S.; SIXSMITH, A. User requirements for Ambient Assisted Living: Results of the SOPRANO project. **Gerontechnology**, v. 7, n. 2, p. 168, 2008. Cited on page 49.

Murata, T. Petri nets: Properties, analysis and applications. **Proceedings of the IEEE**, v. 77, n. 4, p. 541–580, 1989. Cited 4 times on pages 34, 35, 36, and 67.

NEHMER, J.; BECKER, M.; KARSHMER, A.; LAMM, R. Living assistance systems - An ambient intelligence approach -. **Proceedings - International Conference on Software Engineering**, v. 2006, n. January, p. 43–50, 2006. ISSN 02705257. Cited 2 times on pages 13 and 50.

NOF, S. Y.; SILVA, J. R. Perspectives on Manufacturing Automation Under the Digital and Cyber Convergence. **Polytechnica**, Polytechnica, v. 1, n. 1-2, p. 36–47, 2018. ISSN 2520-8497. Cited 4 times on pages 13, 21, 54, and 55.

PAAVILAINEN, P.; KORHONEN, I.; LÖTJÖNEN, J.; CLUITMANS, L.; JYLHÄ, M.; SÄRELÄ, A.; PARTINEN, M. Circadian activity rhythm in demented and non-demented nursing-home residents measured by telemetric actigraphy. **Journal of Sleep Research**, v. 14, n. 1, p. 61–68, 2005. Cited on page 52.

PACINI, F. JOb DEscription LAnguage. **IEEE**, p. 1–83, 2002. Cited on page 57.

PARK, J. H.; SONG, T. H.; JUNG, S. M.; JEON, J. W. XML based robot description language. **ICCAS 2007 - International Conference on Control, Automation and Systems**, p. 2477–2482, 2007. Cited on page 57.

PERES, F.; YANG, J.; GHAZEL, M. A Formal Framework for the Formalization of Informal Requirements. **International Journal of Soft Computing and Software Engineering**, v. 2, n. 8, p. 14–27, 2012. ISSN 2251-7545. Cited on page 65.

PRAMANIK, P. K. D.; PAREEK, G.; NAYYAR, A. **Security and privacy in remote healthcare: Issues, solutions, and standards**. [S.l.]: Elsevier Inc., 2019. 201–225 p. ISBN 9780128169483. Cited 2 times on pages 37 and 39.

QIXIN, W.; WOOK, S.; XUE, L.; ZHENG, Z.; OH, C.; ALSHEBLI, B. K.; CACCAMO, M.; GUNTER, C. A.; GUNTER, E.; HOU, J.; KARAHALIOS, K.; LUI, S. I-living: An open system architecture for assisted living. **Conference Proceedings - IEEE International Conference on Systems, Man and Cybernetics**, v. 5, p. 4268–4275, 2006. ISSN 1062922X. Cited on page 46.

RESPECT, I. KAOS Tutorial.[S.l.]: Objectiver. p. 1–46, 2007. Cited 2 times on pages 13 and 33.

SALMON, A.; FOYO, P. del; SILVA, J. Verificac ao de sistemas automatizados usando a analise dos invariantes. In: **in Proc. Congresso Brasileiro de Automática**. [S.l.: s.n.], 2014. Cited on page 83.

SAPONARA, S.; BACCHILLONE, T. Network architecture, security issues, and hardware implementation of a home area network for smart grid. **Journal of Computer Networks and Communications**, v. 2012, 01 2012. Cited 2 times on pages 40 and 64.

SILVA, J. M.; FOYO, P. del; SALMON, A.; SILVA, J. R. Revisiting requirement engineering for intelligent manufacturing. **Int. Journal of Interactive Design and Manufacturing**, Springer, 2022. Cited on page 58.

SILVA, J. R. Towards a Modeling Discipline for Building an Residence Automation. v. 1, n. Silva 98, p. 560–569, 2003. Cited on page 21.

SILVA, J. R.; MACEDO, E. C. T.; CORREA, Y. G.; MEDEIROS, R. P. A Multilayer Proposal to a Smart Home Applied to Healthcare. **Polytechnica**, Springer International Publishing, v. 4, n. 1, p. 1–14, 2021. ISSN 2520-8497. Disponível em: <https://doi.org/10.1007/s41050-021-00029-7>. Cited 11 times on pages 13, 30, 37, 58, 62, 72, 75, 77, 78, 82, and 90.

SILVA, J. R.; VITAL, E. Towards a Formal Design to Service-Oriented Cloud Manufacturing. **Anais do CBA2020, SBA - Sociedade Brasileira de Automática**, 2020. Cited 2 times on pages 13 and 56.

SILVA, M. Annual Reviews in Control Half a century after Carl Adam Petri ' s Ph . D . thesis : A perspective on the field q. **Annual Reviews in Control**, Elsevier Ltd, v. 37, n. 2, p. 191–219, 2013. ISSN 1367-5788. Cited 2 times on pages 34 and 35.

SOBEIH, A.; VISWANATHAN, M.; HOU, J. C. Check and simulate: A case for incorporating model checking in network simulation. **Proceedings - 2nd ACM and IEEE International Conference on Formal Methods and Models for Co-Design, MEMOCODE'04**, p. 27–36, 2004. Cited on page 70.

TECHNOLOGY, L.; COMMITTEE, S.; COMPUTER, I. **IEEE Standard for Learning Technology — Extensible Markup Language (XML) Schema Definition**. [S.l.: s.n.], 2005. 0_1–46 p. ISBN 0738147109. Cited on page 57.

TOSCHI, G. M.; CAMPOS, L. B.; CUGNASCA, C. E. Home automation networks: A survey. **Computer Standards and Interfaces**, v. 50, n. August 2016, p. 42–54, 2017. ISSN 09205489. Cited on page 40.

Van Lamsweerde, A. Goal-oriented requirements engineering: A guided tour. **Proceedings of the IEEE International Conference on Requirements Engineering**, p. 249–261, 2001. Cited on page 31.

WACKS, K. Home systems standards: Achievements and challenges. **IEEE Communications Magazine**, v. 40, n. 4, p. 152–159, 2002. ISSN 01636804. Cited on page 40.
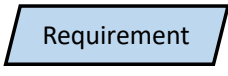
WERNECK, V. M. B.; De Padua Albuquerque Oliveira, A.; Do Prado Leite, J. C. S. Comparing GORE frameworks: I-star and KAOS. **Proceedings of the 12th Workshop on Requirements Engineering, WER 2009**, n. June 2014, p. 15–26, 2009. Cited on page 32.

WILSON, C.; HARGREAVES, T.; HAUXWELL-BALDWIN, R. Smart homes and their users: a systematic analysis and key challenges. **Personal and Ubiquitous Computing**, v. 19, n. 2, p. 463–476, 2015. ISSN 16174909. Cited 3 times on pages 22, 39, and 64.
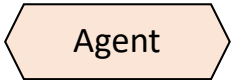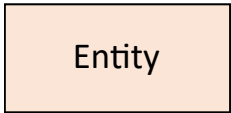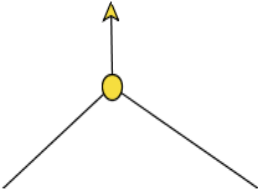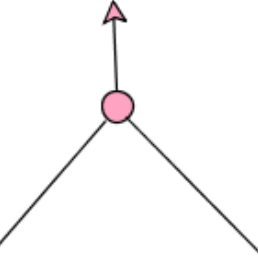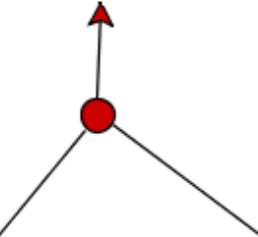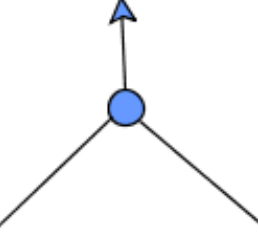
ZAMANI, M. A.; FEREIDUNIAN, A.; MANSOURI, S. S.; Sharifi K, M. A.; BOROOMAND, F.; LESANI, H. A Petri Net-T3SD policy driven method for IT infrastructure selection in smart grid. **2011 IEEE International Systems Conference, SysCon 2011 - Proceedings**, n. September 2015, p. 520–526, 2011. Cited on page 67.

KAOS ELEMENTS FOR AUTOMATED SYSTEMS

Table 3 – Elements of the KAOS method

KAOS ELEMENTS	ELEMENTS DESCRIPTION
Goal	Describes an objective to be achieved by the system or one of the subsystems.
Requirement	A low-level objective with clear satisfaction criteria that can be used in test routines. Satisfaction of the requirements should be reflected (using the objectives diagram) in the justification of other objectives related to these requirements.
Obstacle	An unfavorable condition or constraint to the satisfaction of goals, usually originating in the context or domain of the overall goal.
Expectation	Denote results expected by the agents. It does not have clear criteria for its satisfaction. Therefore their satisfaction - partially defined - does not affect the satisfaction of the associated requirements. However, the satisfaction of expectations can influence the satisfaction of agents, which is important if they are part of the coupling of services.
Domain	Denote systems external to the system under consideration that may be collaborative or supportive. In the case of support systems, they can be associated with invariants or with a hypothesis, in the case of the collaborative system (an external objective to be satisfied), and in this case, it must contribute to the global objective of the system being modeled.

Continues on the next page

KAOS ELEMENTS	ELEMENTS DESCRIPTION
Agent	Active physical objects (system agents), humans, machines, or logical objects (software agents), capable of performing operations that eventually change the state of the system.
Entity	Represent passive and independent objects. Passive objects cannot perform operations; and are independent if they follow the object-oriented model with "behavioral completeness". Its attributes - whose admissible values must be specified - define the state of the system.
Event	Use to start or stop operations. Can be external or produced by operations (they are them made an output of the operation).
OPERATION	Used by different agents to enforce requirements. The operations can create objects, trigger state transitions and activate another series of operations by calling another event or operation.
	Used to designate the existence of a conflict between objectives or an object that prevents the satisfaction of the objective.
	Collector node used to connect objective with its subgoals. Each connection contributes to the satisfaction of the objective in an inclusive way (AND node). Conventionally, if there is a partial order between the sub-goals, it should be represented from left to right. Alternative connections (OR node) will be represented by independent connectors.
	Collector node used to connect agent with goals, expectations or requirements for which this agent is responsible. The same convention follows for inclusive and alternative connections.
	Used to connect (responsibility) to the responsible agent of the requirements or expectation.
	Used to connect the operations with requirements (A requirement is said to be "closed" when this triangular Responsibility-Operationalization-Performance relationship has been established)

APPENDIX

B

SOURCE CODE TO PIPE PNML FILE

```
1
2   <?xml version="1.0" encoding="ISO
       -8859-1"?>
3   <pnml>
4
5     <net id=" id" type="type">
6       <token id="id2" enabled="enable
       " red="red" green="green" blue
       ="blue"/>
7
8         <place id="id3">
9           <graphics>
10             <position x="x" y="y"/>
11           </graphics>
12           <name>
13             <value></value>
14             <graphics>
15               <offset x="x4" y="y5"
       />
16             </graphics>
17           </name>
18           <initialMarking>
19             <value></value>
20             <graphics>
21               <offset x="x7" y="y8"
       />
22             </graphics>
23           </initialMarking>
24           <capacity>
25           <value></value>
26           </capacity>
27         </place>
28       <transition id="id10">
29         <graphics>
30           <position x="x11" y="
       y12"/>
31         </graphics>
32         <name>
33           <value></value>
34           <graphics>
35             <offset x="x14" y="
       y15"/>
36           </graphics>
37         </name>
38         <orientation>
39           <value></value>
40         </orientation>
41         <rate>
42           <value></value>
43         </rate>
44         <timed>
45           <value></value>
46         </timed>
47         <infiniteServer>
48           <value></value>
49         </infiniteServer>
50         <priority>
51           <value></value>
52         </priority>
53       </transition>
54       <arc id="id21" source="source
       " target="target">
55         <graphics/>
```

```
56            <inscription>
57                <value></value>
58          <graphics/>
59            </inscription>
60          <tagged>
61            <value></value>
62          </tagged>
63          <arcpath id="id25" x="x26"
     y="y27" curvePoint="
     curvePoint"/>
64          <type value="value28"/>
65        </arc>
66      </net>
67 </pnml>
```

SOURCE CODE TO KML FILE

```
1  <?kml version="1.0" encoding="ISO
       -8859-1"?>
2  <kml>
3  <Element>
4  <Model>....</Model>
5  <Name>....</Name>
6  <Type>....</Type>
7  <Class>....</Class>
8  <Precondition>....</Precondition>
9  <Postcondition>....</Postcondition
       >
10 <Refinements>
11 <ToRefineAnd>....</ToRefineAnd>
12 <InRefineAnd>....</InRefineAnd>
13 <ToRefineOr>....</ToRefineOr>
14 <InRefineOr>....</InRefineOr>
15 <ConflictTo>....</ConflictTo>
16 <Resolution>....</Resolution>
17 <Obstrution>....</Obstrution>
18 <ExpectationOf>....</ExpectationOf
       >
19 <ConcernsTo>....</ConcernsTo>
20 <AssociateTo>....</AssociateTo>
21 <IsA>....</IsA>
22 <AssignedTo>....</AssignedTo>
23 <ResponsabilityOf>....</
       ResponsabilityOf>
24 <CauseTo>....</CauseTo>
25 <InputTo>....</InputTo>
26 <OutputTo>....</OutputTo>
27 <PerformanceOf>....</PerformanceOf
       >
28 <OperationalizationOf>....</
       OperationalizationOf>
29
30 </Refinements>
31 <Graphics>
32 <Height>....</Height>
33 <Widtht>....</Widtht>
34 <Position>
35 <x>....</x>
36 <y>....</y>
37 </Position>
38 </Graphics>
39 </Element>
40 </kml>
```

KML CODE FOR MONITOR ELDERLY NIGHT SLEEP AND VITAL SIGNS

```xml
1  <?kml version="1.0" encoding="ISO
     -8859-1"?>
2  <kml>
3  <Element>
4  <Model>Goal</Model>
5  <Id>6</Id>
6  <Name>Monitor elderly night sleep
     and vital signs</Name>
7  <Type>Goal</Type>
8  <Refinements>
9  <ToRefineAnd>7</ToRefineAnd>
10 <ToRefineOr>16;20;12</ToRefineOr>
11 </Refinements>
12 <Graphics>
13 <Height>56</Height>
14 <Widtht>170</Widtht>
15 <Position>
16 <x>586.0</x>
17 <y>4.0</y>
18 </Position>
19 </Graphics>
20 </Element>
21 <Element>
22 <Model>Goal</Model>
23 <Id>7</Id>
24 <Name>Monitor Vital Signs</Name>
25 <Type>SubGoal</Type>
26 <Refinements>
27 <InRefineAnd>6</InRefineAnd>
28 <ToRefineOr>22;23;24;28</
     ToRefineOr>
29 </Refinements>
30 <Graphics>
31 <Height>40</Height>
32 <Widtht>143</Widtht>
33 <Position>
34 <x>293.0</x>
35 <y>247.0</y>
36 </Position>
37 </Graphics>
38 </Element>
39 <Element>
40 <Model>Goal</Model>
41 <Id>12</Id>
42 <Name>Automated Activity and Fall
     Detection</Name>
43 <Type>SubGoal</Type>
44 <Refinements>
45 <ToRefineOr>1030</ToRefineOr>
46 <InRefineOr>6</InRefineOr>
47 </Refinements>
48 <Graphics>
49 <Height>50</Height>
50 <Widtht>170</Widtht>
51 <Position>
52 <x>752.0</x>
53 <y>158.0</y>
54 </Position>
55 </Graphics>
```

```
 56 </Element>
 57 <Element>
 58 <Model>Goal</Model>
 59 <Id>16</Id>
 60 <Name>Automated Emergency Call</
       Name>
 61 <Type>SubGoal</Type>
 62 <Refinements>
 63 <ToRefineAnd>57;58</ToRefineAnd>
 64 <ToRefineOr>56</ToRefineOr>
 65 <InRefineOr>6</InRefineOr>
 66 </Refinements>
 67 <Graphics>
 68 <Height>52</Height>
 69 <Widtht>163</Widtht>
 70 <Position>
 71 <x>582.0</x>
 72 <y>116.0</y>
 73 </Position>
 74 </Graphics>
 75 </Element>
 76 <Element>
 77 <Model>Goal</Model>
 78 <Id>20</Id>
 79 <Name>Reminder</Name>
 80 <Type>SubGoal</Type>
 81 <Refinements>
 82 <ToRefineAnd>1301;1145</
       ToRefineAnd>
 83 <InRefineOr>6</InRefineOr>
 84 </Refinements>
 85 <Graphics>
 86 <Height>40</Height>
 87 <Widtht>145</Widtht>
 88 <Position>
 89 <x>868.0</x>
 90 <y>22.0</y>
 91 </Position>
 92 </Graphics>
 93 </Element>
 94 <Element>
 95 <Model>Goal</Model>
 96 <Id>22</Id>
 97 <Name>Blood Pressure
 98 Monitor (BP)</Name>
 99 <Type>Domain</Type>
100 <Refinements>
101 <InRefineOr>7;56;57;58</InRefineOr
       >
102 </Refinements>
103 <Graphics>
104 <Height>53</Height>
105 <Widtht>81</Widtht>
106 <Position>
107 <x>245.0</x>
108 <y>386.0</y>
109 </Position>
110 </Graphics>
111 </Element>
112 <Element>
113 <Model>Goal</Model>
114 <Id>23</Id>
115 <Name>Breathing Rate
116 Monitor (BR)</Name>
117 <Type>Domain</Type>
118 <Refinements>
119 <InRefineOr>7;56;57;58</InRefineOr
       >
120 </Refinements>
121 <Graphics>
122 <Height>48</Height>
123 <Widtht>82</Widtht>
124 <Position>
125 <x>241.0</x>
126 <y>446.0</y>
127 </Position>
128 </Graphics>
129 </Element>
130 <Element>
131 <Model>Goal</Model>
132 <Id>24</Id>
133 <Name>Gycemia Monitor</Name>
134 <Type>Domain</Type>
135 <Refinements>
136 <InRefineOr>7;56;57;58</InRefineOr
       >
137 </Refinements>
138 <Graphics>
139 <Height>40</Height>
140 <Widtht>97</Widtht>
141 <Position>
142 <x>234.0</x>
143 <y>506.0</y>
144 </Position>
```

```
145 </Graphics>
146 </Element>
147 <Element>
148 <Model>Goal</Model>
149 <Id>28</Id>
150 <Name>Body Temperature
151 Monitor (BT)</Name>
152 <Type>Domain</Type>
153 <Refinements>
154 <InRefineOr>7;56;57;58</InRefineOr
        >
155 </Refinements>
156 <Graphics>
157 <Height>49</Height>
158 <Widtht>102</Widtht>
159 <Position>
160 <x>230.0</x>
161 <y>554.0</y>
162 </Position>
163 </Graphics>
164 </Element>
165 <Element>
166 <Model>Goal</Model>
167 <Id>56</Id>
168 <Name>Physician Notification</Name
        >
169 <Type>SubGoal</Type>
170 <Refinements>
171 <ToRefineOr>22;23;24;28;1034</
        ToRefineOr>
172 <InRefineOr>16</InRefineOr>
173 </Refinements>
174 <Graphics>
175 <Height>49</Height>
176 <Widtht>116</Widtht>
177 <Position>
178 <x>392.0</x>
179 <y>305.0</y>
180 </Position>
181 </Graphics>
182 </Element>
183 <Element>
184 <Model>Goal</Model>
185 <Id>57</Id>
186 <Name>Family Notification</Name>
187 <Type>SubGoal</Type>
188 <Refinements>
189 <InRefineAnd>16</InRefineAnd>
190 <ToRefineOr
        >22;23;24;28;1026;1033</
        ToRefineOr>
191 </Refinements>
192 <Graphics>
193 <Height>50</Height>
194 <Widtht>124</Widtht>
195 <Position>
196 <x>568.0</x>
197 <y>228.0</y>
198 </Position>
199 </Graphics>
200 </Element>
201 <Element>
202 <Model>Goal</Model>
203 <Id>58</Id>
204 <Name>Caregiver Notification</Name
        >
205 <Type>SubGoal</Type>
206 <Refinements>
207 <InRefineAnd>16</InRefineAnd>
208 <ToRefineOr>1033;22;23;24;28</
        ToRefineOr>
209 </Refinements>
210 <Graphics>
211 <Height>57</Height>
212 <Widtht>107</Widtht>
213 <Position>
214 <x>660.0</x>
215 <y>316.0</y>
216 </Position>
217 </Graphics>
218 </Element>
219 <Element>
220 <Model>Goal</Model>
221 <Id>1026</Id>
222 <Name>Detect Awaking</Name>
223 <Type>SubGoal</Type>
224 <Refinements>
225 <ToRefineAnd>1034;1035</
        ToRefineAnd>
226 <InRefineAnd>1030</InRefineAnd>
227 <InRefineOr>57</InRefineOr>
228 </Refinements>
229 <Graphics>
230 <Height>40</Height>
```

```
231 <Widtht>119</Widtht>
232 <Position>
233 <x>720.0</x>
234 <y>477.0</y>
235 </Position>
236 </Graphics>
237 </Element>
238 <Element>
239 <Model>Goal</Model>
240 <Id>1030</Id>
241 <Name>Walking Activities
242 Detect</Name>
243 <Type>SubGoal</Type>
244 <Refinements>
245 <ToRefineAnd>1026;1032</
        ToRefineAnd>
246 <ToRefineOr>1031;1033</ToRefineOr>
247 <InRefineOr>12</InRefineOr>
248 </Refinements>
249 <Graphics>
250 <Height>48</Height>
251 <Widtht>129</Widtht>
252 <Position>
253 <x>788.0</x>
254 <y>291.0</y>
255 </Position>
256 </Graphics>
257 </Element>
258 <Element>
259 <Model>Goal</Model>
260 <Id>1031</Id>
261 <Name>Monitor Night Sleep</Name>
262 <Type>SubGoal</Type>
263 <Refinements>
264 <ToRefineOr>1034</ToRefineOr>
265 <InRefineOr>1030</InRefineOr>
266 </Refinements>
267 <Graphics>
268 <Height>50</Height>
269 <Widtht>131</Widtht>
270 <Position>
271 <x>873.0</x>
272 <y>642.0</y>
273 </Position>
274 </Graphics>
275 </Element>
276 <Element>
277 <Model>Goal</Model>
278 <Id>1032</Id>
279 <Name>Light Control</Name>
280 <Type>Domain</Type>
281 <Refinements>
282 <InRefineAnd>1030</InRefineAnd>
283 </Refinements>
284 <Graphics>
285 <Height>40</Height>
286 <Widtht>87</Widtht>
287 <Position>
288 <x>839.0</x>
289 <y>528.0</y>
290 </Position>
291 </Graphics>
292 </Element>
293 <Element>
294 <Model>Goal</Model>
295 <Id>1033</Id>
296 <Name>Fall or stumble
297 Detection</Name>
298 <Type>Domain</Type>
299 <Refinements>
300 <InRefineOr>1030;57;58</InRefineOr
        >
301 </Refinements>
302 <Graphics>
303 <Height>49</Height>
304 <Widtht>98</Widtht>
305 <Position>
306 <x>730.0</x>
307 <y>406.0</y>
308 </Position>
309 </Graphics>
310 </Element>
311 <Element>
312 <Model>Goal</Model>
313 <Id>1034</Id>
314 <Name>CPAP Monitor</Name>
315 <Type>Domain</Type>
316 <Refinements>
317 <InRefineAnd>1026</InRefineAnd>
318 <InRefineOr>1031;56</InRefineOr>
319 </Refinements>
320 <Graphics>
321 <Height>40</Height>
322 <Widtht>89</Widtht>
```

```
323 <Position>
324 <x>634.0</x>
325 <y>604.0</y>
326 </Position>
327 </Graphics>
328 </Element>
329 <Element>
330 <Model>Goal</Model>
331 <Id>1035</Id>
332 <Name>Bed Sensors Monitor</Name>
333 <Type>Domain</Type>
334 <Refinements>
335 <InRefineAnd>1026</InRefineAnd>
336 </Refinements>
337 <Graphics>
338 <Height>51</Height>
339 <Widtht>95</Widtht>
340 <Position>
341 <x>756.0</x>
342 <y>604.0</y>
343 </Position>
344 </Graphics>
345 </Element>
346 <Element>
347 <Model>Goal</Model>
348 <Id>1145</Id>
349 <Name>Alert Confirm</Name>
350 <Type>SubGoal</Type>
351 <Refinements>
352 <InRefineAnd>20</InRefineAnd>
353 <ToRefineOr>1155;1146;1147</
        ToRefineOr>
354 </Refinements>
355 <Graphics>
356 <Height>40</Height>
357 <Widtht>137</Widtht>
358 <Position>
359 <x>1032.0</x>
360 <y>84.0</y>
361 </Position>
362 </Graphics>
363 </Element>
364 <Element>
365 <Model>Goal</Model>
366 <Id>1146</Id>
367 <Name>Family Confirm</Name>
368 <Type>SubGoal</Type>
369 <Refinements>
370 <ToRefineOr>1148</ToRefineOr>
371 <InRefineOr>1145</InRefineOr>
372 </Refinements>
373 <Graphics>
374 <Height>40</Height>
375 <Widtht>111</Widtht>
376 <Position>
377 <x>1340.0</x>
378 <y>138.0</y>
379 </Position>
380 </Graphics>
381 </Element>
382 <Element>
383 <Model>Goal</Model>
384 <Id>1147</Id>
385 <Name>Physician Confirm</Name>
386 <Type>SubGoal</Type>
387 <Refinements>
388 <ToRefineOr>1151</ToRefineOr>
389 <InRefineOr>1145</InRefineOr>
390 </Refinements>
391 <Graphics>
392 <Height>40</Height>
393 <Widtht>124</Widtht>
394 <Position>
395 <x>1516.0</x>
396 <y>140.0</y>
397 </Position>
398 </Graphics>
399 </Element>
400 <Element>
401 <Model>Goal</Model>
402 <Id>1148</Id>
403 <Name>Wait for Family confirmation
        </Name>
404 <Type>SubGoal</Type>
405 <Refinements>
406 <ToRefineOr>1160;1266</ToRefineOr>
407 <InRefineOr>1146</InRefineOr>
408 </Refinements>
409 <Graphics>
410 <Height>54</Height>
411 <Widtht>111</Widtht>
412 <Position>
413 <x>1342.0</x>
414 <y>263.0</y>
```

```
415 </Position>
416 </Graphics>
417 </Element>
418 <Element>
419 <Model>Goal</Model>
420 <Id>1151</Id>
421 <Name>Wait for Physician
        confirmation</Name>
422 <Type>SubGoal</Type>
423 <Refinements>
424 <ToRefineOr>1161;1267</ToRefineOr>
425 <InRefineOr>1147</InRefineOr>
426 </Refinements>
427 <Graphics>
428 <Height>56</Height>
429 <Widtht>127</Widtht>
430 <Position>
431 <x>1517.0</x>
432 <y>240.0</y>
433 </Position>
434 </Graphics>
435 </Element>
436 <Element>
437 <Model>Goal</Model>
438 <Id>1155</Id>
439 <Name>Caregiver Confirm</Name>
440 <Type>SubGoal</Type>
441 <Refinements>
442 <ToRefineOr>1156</ToRefineOr>
443 <InRefineOr>1145</InRefineOr>
444 </Refinements>
445 <Graphics>
446 <Height>40</Height>
447 <Widtht>125</Widtht>
448 <Position>
449 <x>1171.0</x>
450 <y>139.0</y>
451 </Position>
452 </Graphics>
453 </Element>
454 <Element>
455 <Model>Goal</Model>
456 <Id>1156</Id>
457 <Name>Wait for Caregiver
        confirmation</Name>
458 <Type>SubGoal</Type>
459 <Refinements>
460 <ToRefineOr>1162;1265</ToRefineOr>
461 <InRefineOr>1155</InRefineOr>
462 </Refinements>
463 <Graphics>
464 <Height>56</Height>
465 <Widtht>125</Widtht>
466 <Position>
467 <x>1144.0</x>
468 <y>229.0</y>
469 </Position>
470 </Graphics>
471 </Element>
472 <Element>
473 <Model>Goal</Model>
474 <Id>1157</Id>
475 <Name>Patient Confirmation</Name>
476 <Type>Expectation</Type>
477 <Refinements>
478 <InRefineOr>1302</InRefineOr>
479 </Refinements>
480 <Graphics>
481 <Height>40</Height>
482 <Widtht>137</Widtht>
483 <Position>
484 <x>944.0</x>
485 <y>382.0</y>
486 </Position>
487 </Graphics>
488 </Element>
489 <Element>
490 <Model>Goal</Model>
491 <Id>1160</Id>
492 <Name>Family Confirmation</Name>
493 <Type>Expectation</Type>
494 <Refinements>
495 <InRefineOr>1148</InRefineOr>
496 </Refinements>
497 <Graphics>
498 <Height>38</Height>
499 <Widtht>155</Widtht>
500 <Position>
501 <x>1296.0</x>
502 <y>370.0</y>
503 </Position>
504 </Graphics>
505 </Element>
506 <Element>
```

```
507 <Model>Goal</Model>
508 <Id>1161</Id>
509 <Name>Physician Confirmation</Name
        >
510 <Type>Expectation</Type>
511 <Refinements>
512 <InRefineOr>1151</InRefineOr>
513 </Refinements>
514 <Graphics>
515 <Height>39</Height>
516 <Widtht>138</Widtht>
517 <Position>
518 <x>1502.0</x>
519 <y>364.0</y>
520 </Position>
521 </Graphics>
522 </Element>
523 <Element>
524 <Model>Goal</Model>
525 <Id>1162</Id>
526 <Name>Caregiver Confirmation</
        Name>
527 <Type>Expectation</Type>
528 <Refinements>
529 <InRefineOr>1156</InRefineOr>
530 </Refinements>
531 <Graphics>
532 <Height>42</Height>
533 <Widtht>155</Widtht>
534 <Position>
535 <x>1118.0</x>
536 <y>365.0</y>
537 </Position>
538 </Graphics>
539 </Element>
540 <Element>
541 <Model>Goal</Model>
542 <Id>1265</Id>
543 <Name>Sent Family Alert</Name>
544 <Type>Requirement</Type>
545 <Pattern>Achieve</Pattern>
546 <Class>Functional</Class>
547 <Refinements>
548 <InRefineOr>1156</InRefineOr>
549 <Operationalizationof>1330</
        Operationalizationof>
550 </Refinements>
551 <Graphics>
552 <Height>56</Height>
553 <Widtht>94</Widtht>
554 <Position>
555 <x>1237.0</x>
556 <y>616.0</y>
557 </Position>
558 </Graphics>
559 </Element>
560 <Element>
561 <Model>Goal</Model>
562 <Id>1266</Id>
563 <Name>Sent Caregiver Alert</Name>
564 <Type>Requirement</Type>
565 <Pattern>Achieve</Pattern>
566 <Class>Functional</Class>
567 <Refinements>
568 <InRefineOr>1148</InRefineOr>
569 <Operationalizationof>1330</
        Operationalizationof>
570 </Refinements>
571 <Graphics>
572 <Height>57</Height>
573 <Widtht>106</Widtht>
574 <Position>
575 <x>1349.0</x>
576 <y>655.0</y>
577 </Position>
578 </Graphics>
579 </Element>
580 <Element>
581 <Model>Goal</Model>
582 <Id>1267</Id>
583 <Name>Sent Physician Alert</Name>
584 <Type>Requirement</Type>
585 <Pattern>Achieve</Pattern>
586 <Class>Functional</Class>
587 <Refinements>
588 <InRefineOr>1151</InRefineOr>
589 <Operationalizationof>1330</
        Operationalizationof>
590 </Refinements>
591 <Graphics>
592 <Height>52</Height>
593 <Widtht>106</Widtht>
594 <Position>
595 <x>1505.0</x>
```

```
596 <y>680.0</y>
597 </Position>
598 </Graphics>
599 </Element>
600 <Element>
601 <Model>Goal</Model>
602 <Id>1301</Id>
603 <Name>Patient Confirm</Name>
604 <Type>SubGoal</Type>
605 <Refinements>
606 <InRefineAnd>20</InRefineAnd>
607 <ToRefineOr>1302</ToRefineOr>
608 </Refinements>
609 <Graphics>
610 <Height>40</Height>
611 <Widtht>115</Widtht>
612 <Position>
613 <x>968.0</x>
614 <y>152.0</y>
615 </Position>
616 </Graphics>
617 </Element>
618 <Element>
619 <Model>Goal</Model>
620 <Id>1302</Id>
621 <Name>Wait for Patient
        confirmation</Name>
622 <Type>SubGoal</Type>
623 <Refinements>
624 <ToRefineOr>1157;1305</ToRefineOr>
625 <InRefineOr>1301</InRefineOr>
626 </Refinements>
627 <Graphics>
628 <Height>50</Height>
629 <Widtht>120</Widtht>
630 <Position>
631 <x>981.0</x>
632 <y>247.0</y>
633 </Position>
634 </Graphics>
635 </Element>
636 <Element>
637 <Model>Goal</Model>
638 <Id>1305</Id>
639 <Name>Send Patient Alert</Name>
640 <Type>Requirement</Type>
641 <Pattern>Achieve</Pattern>
642 <Class>Functional</Class>
643 <Refinements>
644 <InRefineOr>1302</InRefineOr>
645 <Operationalizationof>1330</
        Operationalizationof>
646 </Refinements>
647 <Graphics>
648 <Height>40</Height>
649 <Widtht>133</Widtht>
650 <Position>
651 <x>1046.0</x>
652 <y>589.0</y>
653 </Position>
654 </Graphics>
655 </Element>
656 <Element>
657 <Model>Operation</Model>
658 <Id>1330</Id>
659 <Name>Sent Notification</Name>
660 <Type>Operation</Type>
661 <Precondition>Reminder message</
        Precondition>
662 <Postcondition>Broadcast of
        message</Postcondition>
663 <Refinements>
664 </Refinements>
665 <Graphics>
666 <Height>49</Height>
667 <Widtht>134</Widtht>
668 <Position>
669 <x>1069.0</x>
670 <y>757.0</y>
671 </Position>
672 </Graphics>
673 </Element>
674 <Element>
675 <Model>Operation</Model>
676 <Id>1331</Id>
677 <Name> Notification</Name>
678 <Type>Event</Type>
679 <Refinements>
680 <CauseTo>1330</CauseTo>
681 </Refinements>
682 <Graphics>
683 <Height>28</Height>
684 <Widtht>102</Widtht>
685 <Position>
```

```
686 <x>1022.0</x>
687 <y>684.0</y>
688 </Position>
689 </Graphics>
690 </Element>
691 <Element>
692 <Model>Object</Model>
693 <Id>1333</Id>
694 <Name>Smartphone
695 -------------------------
696 Mess_Display: Off
697 </Name>
698 <Type>Entity</Type>
699 <Refinements>
700 <InputTo>1330</InputTo>
701 <OutputTo>1330</OutputTo>
702 </Refinements>
703 <Graphics>
704 <Height>58</Height>
705 <Widtht>110</Widtht>
706 <Position>
707 <x>926.0</x>
708 <y>755.0</y>
709 </Position>
710 </Graphics>
711 </Element>
712 <Element>
713 <Model>Responsability</Model>
714 <Id>1334</Id>
715 <Name>Notification system</Name>
716 <Type>Agent</Type>
717 <Class>System Agent</Class>
718 <Refinements>
719 <Performanceof>1330</Performanceof
       >
720 </Refinements>
721 <Graphics>
722 <Height>39</Height>
723 <Widtht>133</Widtht>
724 <Position>
725 <x>1171.0</x>
726 <y>810.0</y>
727 </Position>
728 </Graphics>
729 </Element>
730 <Element>
731 <Model>Responsability</Model>

732 <Id>1374</Id>
733 <Name>Patient</Name>
734 <Type>Agent</Type>
735 <Class>User</Class>
736 <Refinements>
737 <Responsibilityof>1157</
       Responsibilityof>
738 </Refinements>
739 <Graphics>
740 <Height>28</Height>
741 <Widtht>79</Widtht>
742 <Position>
743 <x>1015.0</x>
744 <y>525.0</y>
745 </Position>
746 </Graphics>
747 </Element>
748 <Element>
749 <Model>Responsability</Model>
750 <Id>1375</Id>
751 <Name>Caregiver</Name>
752 <Type>Agent</Type>
753 <Class>User</Class>
754 <Refinements>
755 <Responsibilityof>1162</
       Responsibilityof>
756 </Refinements>
757 <Graphics>
758 <Height>29</Height>
759 <Widtht>98</Widtht>
760 <Position>
761 <x>1181.0</x>
762 <y>505.0</y>
763 </Position>
764 </Graphics>
765 </Element>
766 <Element>
767 <Model>Responsability</Model>
768 <Id>1376</Id>
769 <Name>Physician</Name>
770 <Type>Agent</Type>
771 <Class>User</Class>
772 <Refinements>
773 <Responsibilityof>1161</
       Responsibilityof>
774 </Refinements>
775 <Graphics>
```

```
776 <Height>29</Height>
777 <Widtht>96</Widtht>
778 <Position>
779 <x>1553.0</x>
780 <y>471.0</y>
781 </Position>
782 </Graphics>
783 </Element>
784 <Element>
785 <Model>Responsability</Model>
786 <Id>1377</Id>
787 <Name>Family</Name>
788 <Type>Agent</Type>
789 <Class>User</Class>
790 <Refinements>
791 <Responsibilityof>1160</
        Responsibilityof>
792 </Refinements>
793 <Graphics>
794 <Height>26</Height>
795 <Widtht>83</Widtht>
796 <Position>
797 <x>1372.0</x>
798 <y>497.0</y>
799 </Position>
800 </Graphics>
801 </Element>
802 </kml>
```

PNML CODE FOR MONITOR ELDERLY NIGHT SLEEP AND VITAL SIGNS

```xml
1  <?xml version="1.0" encoding="ISO
      -8859-1"?><pnml>
2  <net id="Net-One" type="P/T net">
3  <token id="Default" enabled="true"
      red="0" green="0" blue="0"/>
4  <place id="Alert Confirm ">
5  <graphics>
6  <position x="1170.0" y="900.0"/>
7  </graphics>
8  <name>
9  <value>Alert Confirm </value>
10 <graphics>
11 <offset x="93.0" y="54.75"/>
12 </graphics>
13 </name>
14 <initialMarking>
15 <value>Default,0</value>
16 <graphics>
17 <offset x="0.0" y="0.0"/>
18 </graphics>
19 </initialMarking>
20 <capacity>
21 <value>0</value>
22 </capacity>
23 </place>
24 <place id="Automated Activity and
      Fall Detection ">
25 <graphics>
26 <position x="1395.0" y="420.0"/>
27 </graphics>
28 <name>
29 <value>Automated Activity and Fall
      Detection </value>
30 <graphics>
31 <offset x="180.5" y="77.75"/>
32 </graphics>
33 </name>
34 <initialMarking>
35 <value>Default,0</value>
36 <graphics>
37 <offset x="0.0" y="0.0"/>
38 </graphics>
39 </initialMarking>
40 <capacity>
41 <value>0</value>
42 </capacity>
43 </place>
44 <place id="Automated Emergency
      Call ">
45 <graphics>
46 <position x="1425.0" y="225.0"/>
47 </graphics>
48 <name>
49 <value>Automated Emergency Call
      </value>
50 <graphics>
51 <offset x="117.75" y="69.5"/>
52 </graphics>
53 </name>
```

```
54 <initialMarking>
55 <value>Default,0</value>
56 <graphics>
57 <offset x="0.0" y="0.0"/>
58 </graphics>
59 </initialMarking>
60 <capacity>
61 <value>0</value>
62 </capacity>
63 </place>
64 <place id="Bed Sensors Monitor ">
65 <graphics>
66 <position x="990.0000000000001" y=
       "510.00000000000006"/>
67 </graphics>
68 <name>
69 <value>Bed Sensors Monitor </value
       >
70 <graphics>
71 <offset x="79.42857142857146" y="
       48.42857142857144"/>
72 </graphics>
73 </name>
74 <initialMarking>
75 <value>Default,0</value>
76 <graphics>
77 <offset x="0.0" y="0.0"/>
78 </graphics>
79 </initialMarking>
80 <capacity>
81 <value>0</value>
82 </capacity>
83 </place>
84 <place id="Broadcast of message">
85 <graphics>
86 <position x="555.0" y="840.0"/>
87 </graphics>
88 <name>
89 <value>Broadcast of message</value
       >
90 <graphics>
91 <offset x="71.5" y="61.5"/>
92 </graphics>
93 </name>
94 <initialMarking>
95 <value>Default,0</value>
96 <graphics>
97 <offset x="0.0" y="0.0"/>
98 </graphics>
99 </initialMarking>
100 <capacity>
101 <value>0</value>
102 </capacity>
103 </place>
104 <place id="Caregiver  Confirmation
        ">
105 <graphics>
106 <position x="969.2857142857143" y=
        "776.4285714285717"/>
107 </graphics>
108 <name>
109 <value>Caregiver  Confirmation </
        value>
110 <graphics>
111 <offset x="79.28571428571429" y="
        -14.285714285714283"/>
112 </graphics>
113 </name>
114 <initialMarking>
115 <value>Default,0</value>
116 <graphics>
117 <offset x="0.0" y="0.0"/>
118 </graphics>
119 </initialMarking>
120 <capacity>
121 <value>0</value>
122 </capacity>
123 </place>
124 <place id="Caregiver Notification
        ">
125 <graphics>
126 <position x="1215.0" y="345.0"/>
127 </graphics>
128 <name>
129 <value>Caregiver Notification </
        value>
130 <graphics>
131 <offset x="148.0" y="28.0"/>
132 </graphics>
133 </name>
134 <initialMarking>
135 <value>Default,0</value>
136 <graphics>
137 <offset x="0.0" y="0.0"/>
```

```
138 </graphics>
139 </initialMarking>
140 <capacity>
141 <value>0</value>
142 </capacity>
143 </place>
144 <place id="CPAP Monitor ">
145 <graphics>
146 <position x="975.0000000000001" y=
        "419.99999999999994"/>
147 </graphics>
148 <name>
149 <value>CPAP Monitor </value>
150 <graphics>
151 <offset x="28.57142857142856" y="
        51.42857142857143"/>
152 </graphics>
153 </name>
154 <initialMarking>
155 <value>Default,0</value>
156 <graphics>
157 <offset x="0.0" y="0.0"/>
158 </graphics>
159 </initialMarking>
160 <capacity>
161 <value>0</value>
162 </capacity>
163 </place>
164 <place id="Detect Awaking ">
165 <graphics>
166 <position x="1170.0" y="495.0"/>
167 </graphics>
168 <name>
169 <value>Detect Awaking </value>
170 <graphics>
171 <offset x="57.142857142857125" y="
        51.14285714285715"/>
172 </graphics>
173 </name>
174 <initialMarking>
175 <value>Default,0</value>
176 <graphics>
177 <offset x="0.0" y="0.0"/>
178 </graphics>
179 </initialMarking>
180 <capacity>
181 <value>0</value>
182 </capacity>
183 </place>
184 <place id="Fall or stumble
        Detection ">
185 <graphics>
186 <position x="1170.0" y="390.0"/>
187 </graphics>
188 <name>
189 <value>Fall or stumble  Detection
        </value>
190 <graphics>
191 <offset x="16.777777777777736" y="
        -1.6388888888888902"/>
192 </graphics>
193 </name>
194 <initialMarking>
195 <value>Default,0</value>
196 <graphics>
197 <offset x="0.0" y="0.0"/>
198 </graphics>
199 </initialMarking>
200 <capacity>
201 <value>0</value>
202 </capacity>
203 </place>
204 <place id="Family Confirmation ">
205 <graphics>
206 <position x="975.0" y="900.0"/>
207 </graphics>
208 <name>
209 <value>Family Confirmation </value
        >
210 <graphics>
211 <offset x="42.07142857142857" y="
        57.821428571428555"/>
212 </graphics>
213 </name>
214 <initialMarking>
215 <value>Default,0</value>
216 <graphics>
217 <offset x="0.0" y="0.0"/>
218 </graphics>
219 </initialMarking>
220 <capacity>
221 <value>0</value>
222 </capacity>
223 </place>
```

```
224 <place id="Family Notification ">
225 <graphics>
226 <position x="1215.0" y="285.0"/>
227 </graphics>
228 <name>
229 <value>Family Notification </value
      >
230 <graphics>
231 <offset x="128.0" y="0.0"/>
232 </graphics>
233 </name>
234 <initialMarking>
235 <value>Default,0</value>
236 <graphics>
237 <offset x="0.0" y="0.0"/>
238 </graphics>
239 </initialMarking>
240 <capacity>
241 <value>0</value>
242 </capacity>
243 </place>
244 <place id="Gycemia Monitor ">
245 <graphics>
246 <position x="690.0" y="270.0"/>
247 </graphics>
248 <name>
249 <value>Gycemia Monitor </value>
250 <graphics>
251 <offset x="71.57142857142861" y="
      50.85714285714287"/>
252 </graphics>
253 </name>
254 <initialMarking>
255 <value>Default,0</value>
256 <graphics>
257 <offset x="0.0" y="0.0"/>
258 </graphics>
259 </initialMarking>
260 <capacity>
261 <value>0</value>
262 </capacity>
263 </place>
264 <place id="Light Control ">
265 <graphics>
266 <position x="1155.0" y="600.0"/>
267 </graphics>
268 <name>
269 <value>Light Control </value>
270 <graphics>
271 <offset x="58.5" y="51.0"/>
272 </graphics>
273 </name>
274 <initialMarking>
275 <value>Default,0</value>
276 <graphics>
277 <offset x="0.0" y="0.0"/>
278 </graphics>
279 </initialMarking>
280 <capacity>
281 <value>0</value>
282 </capacity>
283 </place>
284 <place id="Monitor (BP) ">
285 <graphics>
286 <position x="690.0" y="120.0"/>
287 </graphics>
288 <name>
289 <value>Monitor (BP) </value>
290 <graphics>
291 <offset x="58.857142857142875" y="
      54.71428571428572"/>
292 </graphics>
293 </name>
294 <initialMarking>
295 <value>Default,0</value>
296 <graphics>
297 <offset x="0.0" y="0.0"/>
298 </graphics>
299 </initialMarking>
300 <capacity>
301 <value>0</value>
302 </capacity>
303 </place>
304 <place id="Monitor (BR) ">
305 <graphics>
306 <position x="690.0" y="195.0"/>
307 </graphics>
308 <name>
309 <value>Monitor (BR) </value>
310 <graphics>
311 <offset x="67.14285714285712" y="
      56.14285714285714"/>
312 </graphics>
313 </name>
```

```
314 <initialMarking>                          359 </initialMarking>
315 <value>Default,0</value>                  360 <capacity>
316 <graphics>                                361 <value>0</value>
317 <offset x="0.0" y="0.0"/>                 362 </capacity>
318 </graphics>                               363 </place>
319 </initialMarking>                         364 <place id="Monitor night sleep and
320 <capacity>                                        vital signs   ">
321 <value>0</value>                          365 <graphics>
322 </capacity>                               366 <position x="1590.0" y="300.0"/>
323 </place>                                  367 </graphics>
324 <place id="Monitor (BT) ">               368 <name>
325 <graphics>                                369 <value>Monitor night sleep and
326 <position x="690.0" y="330.0"/>                   vital signs   </value>
327 </graphics>                               370 <graphics>
328 <name>                                    371 <offset x="205.87301587301585" y="
329 <value>Monitor (BT) </value>                     -0.7420634920635107"/>
330 <graphics>                                372 </graphics>
331 <offset x="66.8412698412699" y="          373 </name>
        54.84126984126984"/>               374 <initialMarking>
332 </graphics>                               375 <value>Default,1</value>
333 </name>                                   376 <graphics>
334 <initialMarking>                          377 <offset x="0.0" y="0.0"/>
335 <value>Default,0</value>                  378 </graphics>
336 <graphics>                                379 </initialMarking>
337 <offset x="0.0" y="0.0"/>                 380 <capacity>
338 </graphics>                               381 <value>0</value>
339 </initialMarking>                         382 </capacity>
340 <capacity>                                383 </place>
341 <value>0</value>                          384 <place id="Monitor Vital Signs   "
342 </capacity>                                       >
343 </place>                                  385 <graphics>
344 <place id="Monitor Night Sleep ">        386 <position x="1425.0" y="120.0"/>
345 <graphics>                                387 </graphics>
346 <position x="1155.0" y="435.0"/>          388 <name>
347 </graphics>                               389 <value>Monitor Vital Signs   </
348 <name>                                            value>
349 <value>Monitor Night Sleep </value        390 <graphics>
        >                                  391 <offset x="66.75" y="69.25"/>
350 <graphics>                                392 </graphics>
351 <offset x="57.5" y="47.0"/>              393 </name>
352 </graphics>                               394 <initialMarking>
353 </name>                                   395 <value>Default,0</value>
354 <initialMarking>                          396 <graphics>
355 <value>Default,0</value>                  397 <offset x="0.0" y="0.0"/>
356 <graphics>                                398 </graphics>
357 <offset x="0.0" y="0.0"/>                 399 </initialMarking>
358 </graphics>                               400 <capacity>
```

```
401 <value>0</value>
402 </capacity>
403 </place>
404 <place id="Patient Confirm ">
405 <graphics>
406 <position x="1155.0" y="660.0"/>
407 </graphics>
408 <name>
409 <value>Patient Confirm </value>
410 <graphics>
411 <offset x="85.0" y="58.0"/>
412 </graphics>
413 </name>
414 <initialMarking>
415 <value>Default,0</value>
416 <graphics>
417 <offset x="0.0" y="0.0"/>
418 </graphics>
419 </initialMarking>
420 <capacity>
421 <value>0</value>
422 </capacity>
423 </place>
424 <place id="Patient Confirmation ">
425 <graphics>
426 <position x="975.0" y="630.0"/>
427 </graphics>
428 <name>
429 <value>Patient Confirmation </
        value>
430 <graphics>
431 <offset x="58.21428571428555" y="
        -11.928571428571502"/>
432 </graphics>
433 </name>
434 <initialMarking>
435 <value>Default,0</value>
436 <graphics>
437 <offset x="0.0" y="0.0"/>
438 </graphics>
439 </initialMarking>
440 <capacity>
441 <value>0</value>
442 </capacity>
443 </place>
444 <place id="Physician Confirmation
        ">
445 <graphics>
446 <position x="1003.0" y="1051.0"/>
447 </graphics>
448 <name>
449 <value>Physician Confirmation </
        value>
450 <graphics>
451 <offset x="135.64285714285722" y="
        3.607142857143117"/>
452 </graphics>
453 </name>
454 <initialMarking>
455 <value>Default,0</value>
456 <graphics>
457 <offset x="0.0" y="0.0"/>
458 </graphics>
459 </initialMarking>
460 <capacity>
461 <value>0</value>
462 </capacity>
463 </place>
464 <place id="Physician Notification
        ">
465 <graphics>
466 <position x="1215.0" y="225.0"/>
467 </graphics>
468 <name>
469 <value>Physician Notification </
        value>
470 <graphics>
471 <offset x="117.67857142857143" y="
        -9.464285714285714"/>
472 </graphics>
473 </name>
474 <initialMarking>
475 <value>Default,0</value>
476 <graphics>
477 <offset x="0.0" y="0.0"/>
478 </graphics>
479 </initialMarking>
480 <capacity>
481 <value>0</value>
482 </capacity>
483 </place>
484 <place id="Reminder">
485 <graphics>
486 <position x="1395.0" y="705.0"/>
```

```
487 </graphics>
488 <name>
489 <value>Reminder</value>
490 <graphics>
491 <offset x="68.0" y="46.25"/>
492 </graphics>
493 </name>
494 <initialMarking>
495 <value>Default,0</value>
496 <graphics>
497 <offset x="0.0" y="0.0"/>
498 </graphics>
499 </initialMarking>
500 <capacity>
501 <value>0</value>
502 </capacity>
503 </place>
504 <place id="Reminder message">
505 <graphics>
506 <position x="420.0" y="840.0"/>
507 </graphics>
508 <name>
509 <value>Reminder message</value>
510 <graphics>
511 <offset x="54.0" y="65.5"/>
512 </graphics>
513 </name>
514 <initialMarking>
515 <value>Default,0</value>
516 <graphics>
517 <offset x="0.0" y="0.0"/>
518 </graphics>
519 </initialMarking>
520 <capacity>
521 <value>0</value>
522 </capacity>
523 </place>
524 <place id="Wait for Caregiver
        confirmation ">
525 <graphics>
526 <position x="976.4285714285714" y=
        "834.2857142857142"/>
527 </graphics>
528 <name>
529 <value>Wait for Caregiver
        confirmation </value>
530 <graphics>
531 <offset x="149.07142857142844" y="
        50.750000000000014"/>
532 </graphics>
533 </name>
534 <initialMarking>
535 <value>Default,0</value>
536 <graphics>
537 <offset x="0.0" y="0.0"/>
538 </graphics>
539 </initialMarking>
540 <capacity>
541 <value>0</value>
542 </capacity>
543 </place>
544 <place id="Wait for Family
        confirmation ">
545 <graphics>
546 <position x="979.0000000000001" y=
        "965.0000000000001"/>
547 </graphics>
548 <name>
549 <value>Wait for Family
        confirmation </value>
550 <graphics>
551 <offset x="158.39285714285728" y="
        54.28571428571429"/>
552 </graphics>
553 </name>
554 <initialMarking>
555 <value>Default,0</value>
556 <graphics>
557 <offset x="0.0" y="0.0"/>
558 </graphics>
559 </initialMarking>
560 <capacity>
561 <value>0</value>
562 </capacity>
563 </place>
564 <place id="Wait for Patient
        confirmation ">
565 <graphics>
566 <position x="983.0000000000001" y=
        "693.9999999999995"/>
567 </graphics>
568 <name>
569 <value>Wait for Patient
        confirmation </value>
```

```
570 <graphics>
571 <offset x="35.14285714285714" y="
        -2.1785714285714266"/>
572 </graphics>
573 </name>
574 <initialMarking>
575 <value>Default,0</value>
576 <graphics>
577 <offset x="0.0" y="0.0"/>
578 </graphics>
579 </initialMarking>
580 <capacity>
581 <value>0</value>
582 </capacity>
583 </place>
584 <place id="Wait for Physician
        confirmation ">
585 <graphics>
586 <position x="1015.2857142857143" y
        ="1122.5714285714284"/>
587 </graphics>
588 <name>
589 <value>Wait for Physician
        confirmation </value>
590 <graphics>
591 <offset x="103.25" y="61.75"/>
592 </graphics>
593 </name>
594 <initialMarking>
595 <value>Default,0</value>
596 <graphics>
597 <offset x="0.0" y="0.0"/>
598 </graphics>
599 </initialMarking>
600 <capacity>
601 <value>0</value>
602 </capacity>
603 </place>
604 <transition id="Notification
        system ">
605 <graphics>
606 <position x="480.0" y="840.0"/>
607 </graphics>
608 <name>
609 <value>Notification system </value
        >
610 <graphics>
611 <offset x="67.5" y="-22.5"/>
612 </graphics>
613 </name>
614 <orientation>
615 <value>0</value>
616 </orientation>
617 <rate>
618 <value>1.0</value>
619 </rate>
620 <timed>
621 <value>false</value>
622 </timed>
623 <infiniteServer>
624 <value>false</value>
625 </infiniteServer>
626 <priority>
627 <value>1</value>
628 </priority>
629 </transition>
630 <transition id="T0">
631 <graphics>
632 <position x="1502.8571428571427" y
        ="120.71428571428571"/>
633 </graphics>
634 <name>
635 <value>T0</value>
636 <graphics>
637 <offset x="27.5" y="-2.5"/>
638 </graphics>
639 </name>
640 <orientation>
641 <value>0</value>
642 </orientation>
643 <rate>
644 <value>1.0</value>
645 </rate>
646 <timed>
647 <value>false</value>
648 </timed>
649 <infiniteServer>
650 <value>false</value>
651 </infiniteServer>
652 <priority>
653 <value>1</value>
654 </priority>
655 </transition>
656 <transition id="T1">
```

```
657 <graphics>
658 <position x="1500.0" y="225.0"/>
659 </graphics>
660 <name>
661 <value>T1</value>
662 <graphics>
663 <offset x="27.5" y="-5.0"/>
664 </graphics>
665 </name>
666 <orientation>
667 <value>0</value>
668 </orientation>
669 <rate>
670 <value>1.0</value>
671 </rate>
672 <timed>
673 <value>false</value>
674 </timed>
675 <infiniteServer>
676 <value>false</value>
677 </infiniteServer>
678 <priority>
679 <value>1</value>
680 </priority>
681 </transition>
682 <transition id="T10">
683 <graphics>
684 <position x="1290.0" y="420.0"/>
685 </graphics>
686 <name>
687 <value>T10</value>
688 <graphics>
689 <offset x="27.5" y="-1.25"/>
690 </graphics>
691 </name>
692 <orientation>
693 <value>0</value>
694 </orientation>
695 <rate>
696 <value>1.0</value>
697 </rate>
698 <timed>
699 <value>false</value>
700 </timed>
701 <infiniteServer>
702 <value>false</value>
703 </infiniteServer>
704 <priority>
705 <value>1</value>
706 </priority>
707 </transition>
708 <transition id="T11">
709 <graphics>
710 <position x="1290.0" y="540.0"/>
711 </graphics>
712 <name>
713 <value>T11</value>
714 <graphics>
715 <offset x="22.5" y="-2.5"/>
716 </graphics>
717 </name>
718 <orientation>
719 <value>0</value>
720 </orientation>
721 <rate>
722 <value>1.0</value>
723 </rate>
724 <timed>
725 <value>false</value>
726 </timed>
727 <infiniteServer>
728 <value>false</value>
729 </infiniteServer>
730 <priority>
731 <value>1</value>
732 </priority>
733 </transition>
734 <transition id="T12">
735 <graphics>
736 <position x="1290.0" y="480.0"/>
737 </graphics>
738 <name>
739 <value>T12</value>
740 <graphics>
741 <offset x="26.25" y="-2.5"/>
742 </graphics>
743 </name>
744 <orientation>
745 <value>0</value>
746 </orientation>
747 <rate>
748 <value>1.0</value>
749 </rate>
750 <timed>
```

```
751 <value>false</value>
752 </timed>
753 <infiniteServer>
754 <value>false</value>
755 </infiniteServer>
756 <priority>
757 <value>1</value>
758 </priority>
759 </transition>
760 <transition id="T13">
761 <graphics>
762 <position x="1080.0" y="495.0"/>
763 </graphics>
764 <name>
765 <value>T13</value>
766 <graphics>
767 <offset x="23.75" y="-1.25"/>
768 </graphics>
769 </name>
770 <orientation>
771 <value>0</value>
772 </orientation>
773 <rate>
774 <value>1.0</value>
775 </rate>
776 <timed>
777 <value>false</value>
778 </timed>
779 <infiniteServer>
780 <value>false</value>
781 </infiniteServer>
782 <priority>
783 <value>1</value>
784 </priority>
785 </transition>
786 <transition id="T14">
787 <graphics>
788 <position x="1065.0000000000005" y
        ="419.99999999999994"/>
789 </graphics>
790 <name>
791 <value>T14</value>
792 <graphics>
793 <offset x="25.0" y="-1.25"/>
794 </graphics>
795 </name>
796 <orientation>
797 <value>0</value>
798 </orientation>
799 <rate>
800 <value>1.0</value>
801 </rate>
802 <timed>
803 <value>false</value>
804 </timed>
805 <infiniteServer>
806 <value>false</value>
807 </infiniteServer>
808 <priority>
809 <value>1</value>
810 </priority>
811 </transition>
812 <transition id="T15">
813 <graphics>
814 <position x="1320.0" y="705.0"/>
815 </graphics>
816 <name>
817 <value>T15</value>
818 <graphics>
819 <offset x="26.0" y="51.0"/>
820 </graphics>
821 </name>
822 <orientation>
823 <value>0</value>
824 </orientation>
825 <rate>
826 <value>1.0</value>
827 </rate>
828 <timed>
829 <value>false</value>
830 </timed>
831 <infiniteServer>
832 <value>false</value>
833 </infiniteServer>
834 <priority>
835 <value>1</value>
836 </priority>
837 </transition>
838 <transition id="T16">
839 <graphics>
840 <position x="1080.0" y="630.0"/>
841 </graphics>
842 <name>
843 <value>T16</value>
```

```
844 <graphics>
845 <offset x="27.0" y="43.0"/>
846 </graphics>
847 </name>
848 <orientation>
849 <value>0</value>
850 </orientation>
851 <rate>
852 <value>1.0</value>
853 </rate>
854 <timed>
855 <value>false</value>
856 </timed>
857 <infiniteServer>
858 <value>false</value>
859 </infiniteServer>
860 <priority>
861 <value>1</value>
862 </priority>
863 </transition>
864 <transition id="T17">
865 <graphics>
866 <position x="1080.0" y="690.0"/>
867 </graphics>
868 <name>
869 <value>T17</value>
870 <graphics>
871 <offset x="29.0" y="43.0"/>
872 </graphics>
873 </name>
874 <orientation>
875 <value>0</value>
876 </orientation>
877 <rate>
878 <value>1.0</value>
879 </rate>
880 <timed>
881 <value>false</value>
882 </timed>
883 <infiniteServer>
884 <value>false</value>
885 </infiniteServer>
886 <priority>
887 <value>1</value>
888 </priority>
889 </transition>
890 <transition id="T18">

891 <graphics>
892 <position x="630.0" y="840.0"/>
893 </graphics>
894 <name>
895 <value>T18</value>
896 <graphics>
897 <offset x="-5.0" y="35.0"/>
898 </graphics>
899 </name>
900 <orientation>
901 <value>0</value>
902 </orientation>
903 <rate>
904 <value>1.0</value>
905 </rate>
906 <timed>
907 <value>false</value>
908 </timed>
909 <infiniteServer>
910 <value>false</value>
911 </infiniteServer>
912 <priority>
913 <value>1</value>
914 </priority>
915 </transition>
916 <transition id="T2">
917 <graphics>
918 <position x="1515.0" y="420.0"/>
919 </graphics>
920 <name>
921 <value>T2</value>
922 <graphics>
923 <offset x="20.0" y="-6.25"/>
924 </graphics>
925 </name>
926 <orientation>
927 <value>0</value>
928 </orientation>
929 <rate>
930 <value>1.0</value>
931 </rate>
932 <timed>
933 <value>false</value>
934 </timed>
935 <infiniteServer>
936 <value>false</value>
937 </infiniteServer>
```

```
938 <priority>
939 <value>1</value>
940 </priority>
941 </transition>
942 <transition id="T20">
943 <graphics>
944 <position x="1065.0" y="780.0"/>
945 </graphics>
946 <name>
947 <value>T20</value>
948 <graphics>
949 <offset x="22.5" y="-5.0"/>
950 </graphics>
951 </name>
952 <orientation>
953 <value>0</value>
954 </orientation>
955 <rate>
956 <value>1.0</value>
957 </rate>
958 <timed>
959 <value>false</value>
960 </timed>
961 <infiniteServer>
962 <value>false</value>
963 </infiniteServer>
964 <priority>
965 <value>1</value>
966 </priority>
967 </transition>
968 <transition id="T21">
969 <graphics>
970 <position x="1065.0" y="825.0"/>
971 </graphics>
972 <name>
973 <value>T21</value>
974 <graphics>
975 <offset x="26.25" y="-2.5"/>
976 </graphics>
977 </name>
978 <orientation>
979 <value>0</value>
980 </orientation>
981 <rate>
982 <value>1.0</value>
983 </rate>
984 <timed>
```

```
985 <value>false</value>
986 </timed>
987 <infiniteServer>
988 <value>false</value>
989 </infiniteServer>
990 <priority>
991 <value>1</value>
992 </priority>
993 </transition>
994 <transition id="T22">
995 <graphics>
996 <position x="1065.0" y="900.0"/>
997 </graphics>
998 <name>
999 <value>T22</value>
1000 <graphics>
1001 <offset x="25.0" y="-2.5"/>
1002 </graphics>
1003 </name>
1004 <orientation>
1005 <value>0</value>
1006 </orientation>
1007 <rate>
1008 <value>1.0</value>
1009 </rate>
1010 <timed>
1011 <value>false</value>
1012 </timed>
1013 <infiniteServer>
1014 <value>false</value>
1015 </infiniteServer>
1016 <priority>
1017 <value>1</value>
1018 </priority>
1019 </transition>
1020 <transition id="T23">
1021 <graphics>
1022 <position x="1065.0" y="960.0"/>
1023 </graphics>
1024 <name>
1025 <value>T23</value>
1026 <graphics>
1027 <offset x="25.0" y="0.0"/>
1028 </graphics>
1029 </name>
1030 <orientation>
1031 <value>0</value>
```

```
1032 </orientation>
1033 <rate>
1034 <value>1.0</value>
1035 </rate>
1036 <timed>
1037 <value>false</value>
1038 </timed>
1039 <infiniteServer>
1040 <value>false</value>
1041 </infiniteServer>
1042 <priority>
1043 <value>1</value>
1044 </priority>
1045 </transition>
1046 <transition id="T24">
1047 <graphics>
1048 <position x="1125.0" y="1051.0"/>
1049 </graphics>
1050 <name>
1051 <value>T24</value>
1052 <graphics>
1053 <offset x="-5.0" y="35.0"/>
1054 </graphics>
1055 </name>
1056 <orientation>
1057 <value>0</value>
1058 </orientation>
1059 <rate>
1060 <value>1.0</value>
1061 </rate>
1062 <timed>
1063 <value>false</value>
1064 </timed>
1065 <infiniteServer>
1066 <value>false</value>
1067 </infiniteServer>
1068 <priority>
1069 <value>1</value>
1070 </priority>
1071 </transition>
1072 <transition id="T25">
1073 <graphics>
1074 <position x="1139.0" y="1117.0"/>
1075 </graphics>
1076 <name>
1077 <value>T25</value>
1078 <graphics>
1079 <offset x="-5.0" y="35.0"/>
1080 </graphics>
1081 </name>
1082 <orientation>
1083 <value>0</value>
1084 </orientation>
1085 <rate>
1086 <value>1.0</value>
1087 </rate>
1088 <timed>
1089 <value>false</value>
1090 </timed>
1091 <infiniteServer>
1092 <value>false</value>
1093 </infiniteServer>
1094 <priority>
1095 <value>1</value>
1096 </priority>
1097 </transition>
1098 <transition id="T26">
1099 <graphics>
1100 <position x="411.4285714285714" y=
          "389.99999999999994"/>
1101 </graphics>
1102 <name>
1103 <value>T26</value>
1104 <graphics>
1105 <offset x="-5.0" y="35.0"/>
1106 </graphics>
1107 </name>
1108 <orientation>
1109 <value>0</value>
1110 </orientation>
1111 <rate>
1112 <value>1.0</value>
1113 </rate>
1114 <timed>
1115 <value>false</value>
1116 </timed>
1117 <infiniteServer>
1118 <value>false</value>
1119 </infiniteServer>
1120 <priority>
1121 <value>1</value>
1122 </priority>
1123 </transition>
1124 <transition id="T3">
```

```
1125 <graphics>
1126 <position x="1530.0" y="600.0"/>
1127 </graphics>
1128 <name>
1129 <value>T3</value>
1130 <graphics>
1131 <offset x="18.75" y="-5.0"/>
1132 </graphics>
1133 </name>
1134 <orientation>
1135 <value>0</value>
1136 </orientation>
1137 <rate>
1138 <value>1.0</value>
1139 </rate>
1140 <timed>
1141 <value>false</value>
1142 </timed>
1143 <infiniteServer>
1144 <value>false</value>
1145 </infiniteServer>
1146 <priority>
1147 <value>1</value>
1148 </priority>
1149 </transition>
1150 <transition id="T4">
1151 <graphics>
1152 <position x="1290.0" y="315.0"/>
1153 </graphics>
1154 <name>
1155 <value>T4</value>
1156 <graphics>
1157 <offset x="26.0" y="-0.5"/>
1158 </graphics>
1159 </name>
1160 <orientation>
1161 <value>0</value>
1162 </orientation>
1163 <rate>
1164 <value>1.0</value>
1165 </rate>
1166 <timed>
1167 <value>false</value>
1168 </timed>
1169 <infiniteServer>
1170 <value>false</value>
1171 </infiniteServer>
1172 <priority>
1173 <value>1</value>
1174 </priority>
1175 </transition>
1176 <transition id="T5">
1177 <graphics>
1178 <position x="1290.0" y="225.0"/>
1179 </graphics>
1180 <name>
1181 <value>T5</value>
1182 <graphics>
1183 <offset x="37.5" y="6.25"/>
1184 </graphics>
1185 </name>
1186 <orientation>
1187 <value>0</value>
1188 </orientation>
1189 <rate>
1190 <value>1.0</value>
1191 </rate>
1192 <timed>
1193 <value>false</value>
1194 </timed>
1195 <infiniteServer>
1196 <value>false</value>
1197 </infiniteServer>
1198 <priority>
1199 <value>1</value>
1200 </priority>
1201 </transition>
1202 <transition id="T6">
1203 <graphics>
1204 <position x="795.0" y="120.0"/>
1205 </graphics>
1206 <name>
1207 <value>T6</value>
1208 <graphics>
1209 <offset x="25.0" y="-2.5"/>
1210 </graphics>
1211 </name>
1212 <orientation>
1213 <value>0</value>
1214 </orientation>
1215 <rate>
1216 <value>1.0</value>
1217 </rate>
1218 <timed>
```

```
1219 <value>false</value>
1220 </timed>
1221 <infiniteServer>
1222 <value>false</value>
1223 </infiniteServer>
1224 <priority>
1225 <value>1</value>
1226 </priority>
1227 </transition>
1228 <transition id="T7">
1229 <graphics>
1230 <position x="795.0" y="195.0"/>
1231 </graphics>
1232 <name>
1233 <value>T7</value>
1234 <graphics>
1235 <offset x="25.0" y="-1.25"/>
1236 </graphics>
1237 </name>
1238 <orientation>
1239 <value>0</value>
1240 </orientation>
1241 <rate>
1242 <value>1.0</value>
1243 </rate>
1244 <timed>
1245 <value>false</value>
1246 </timed>
1247 <infiniteServer>
1248 <value>false</value>
1249 </infiniteServer>
1250 <priority>
1251 <value>1</value>
1252 </priority>
1253 </transition>
1254 <transition id="T8">
1255 <graphics>
1256 <position x="795.0" y="270.0"/>
1257 </graphics>
1258 <name>
1259 <value>T8</value>
1260 <graphics>
1261 <offset x="25.0" y="-3.75"/>
1262 </graphics>
1263 </name>
1264 <orientation>
1265 <value>0</value>
1266 </orientation>
1267 <rate>
1268 <value>1.0</value>
1269 </rate>
1270 <timed>
1271 <value>false</value>
1272 </timed>
1273 <infiniteServer>
1274 <value>false</value>
1275 </infiniteServer>
1276 <priority>
1277 <value>1</value>
1278 </priority>
1279 </transition>
1280 <transition id="T9">
1281 <graphics>
1282 <position x="795.0" y="330.0"/>
1283 </graphics>
1284 <name>
1285 <value>T9</value>
1286 <graphics>
1287 <offset x="23.75" y="-1.25"/>
1288 </graphics>
1289 </name>
1290 <orientation>
1291 <value>0</value>
1292 </orientation>
1293 <rate>
1294 <value>1.0</value>
1295 </rate>
1296 <timed>
1297 <value>false</value>
1298 </timed>
1299 <infiniteServer>
1300 <value>false</value>
1301 </infiniteServer>
1302 <priority>
1303 <value>1</value>
1304 </priority>
1305 </transition>
1306 <arc id="Alert Confirm  to T15"
         source="Alert Confirm " target
         ="T15">
1307 <graphics/>
1308 <inscription>
1309 <value>Default,1</value>
1310 <graphics/>
```

```
1311 </inscription>
1312 <tagged>
1313 <value>false</value>
1314 </tagged>
1315 <type value="normal"/>
1316 </arc>
1317 <arc id="Automated Activity and
         Fall Detection   to T2" source
         ="Automated Activity and Fall
         Detection  " target="T2">
1318 <graphics/>
1319 <inscription>
1320 <value>Default,1</value>
1321 <graphics/>
1322 </inscription>
1323 <tagged>
1324 <value>false</value>
1325 </tagged>
1326 <type value="normal"/>
1327 </arc>
1328 <arc id="Automated Emergency Call
          to T1" source="Automated
         Emergency Call  " target="T1">
1329 <graphics/>
1330 <inscription>
1331 <value>Default,1</value>
1332 <graphics/>
1333 </inscription>
1334 <tagged>
1335 <value>false</value>
1336 </tagged>
1337 <type value="normal"/>
1338 </arc>
1339 <arc id="Bed Sensors Monitor  to
         T13" source="Bed Sensors
         Monitor " target="T13">
1340 <graphics/>
1341 <inscription>
1342 <value>Default,1</value>
1343 <graphics/>
1344 </inscription>
1345 <tagged>
1346 <value>false</value>
1347 </tagged>
1348 <type value="normal"/>
1349 </arc>
```

```
1350 <arc id="Broadcast of message to
         T18" source="Broadcast of
         message" target="T18">
1351 <graphics/>
1352 <inscription>
1353 <value>Default,1</value>
1354 <graphics/>
1355 </inscription>
1356 <tagged>
1357 <value>false</value>
1358 </tagged>
1359 <type value="normal"/>
1360 </arc>
1361 <arc id="Caregiver  Confirmation
         to T20" source="Caregiver
         Confirmation " target="T20">
1362 <graphics/>
1363 <inscription>
1364 <value>Default,1</value>
1365 <graphics/>
1366 </inscription>
1367 <tagged>
1368 <value>false</value>
1369 </tagged>
1370 <type value="normal"/>
1371 </arc>
1372 <arc id="Caregiver  Confirmation
         to T21" source="Caregiver
         Confirmation " target="T21">
1373 <graphics/>
1374 <inscription>
1375 <value/>
1376 <graphics/>
1377 </inscription>
1378 <tagged>
1379 <value/>
1380 </tagged>
1381 <type value="inhibitor"/>
1382 </arc>
1383 <arc id="Caregiver Notification
         to T4" source="Caregiver
         Notification " target="T4">
1384 <graphics/>
1385 <inscription>
1386 <value>Default,1</value>
1387 <graphics/>
1388 </inscription>
```

```
1389 <tagged>
1390 <value>false</value>
1391 </tagged>
1392 <type value="normal"/>
1393 </arc>
1394 <arc id="CPAP Monitor  to T13"
         source="CPAP Monitor " target=
         "T13">
1395 <graphics/>
1396 <inscription>
1397 <value>Default,1</value>
1398 <graphics/>
1399 </inscription>
1400 <tagged>
1401 <value>false</value>
1402 </tagged>
1403 <type value="normal"/>
1404 </arc>
1405 <arc id="CPAP Monitor  to T14"
         source="CPAP Monitor " target=
         "T14">
1406 <graphics/>
1407 <inscription>
1408 <value>Default,1</value>
1409 <graphics/>
1410 </inscription>
1411 <tagged>
1412 <value>false</value>
1413 </tagged>
1414 <type value="normal"/>
1415 </arc>
1416 <arc id="Detect Awaking  to T11"
         source="Detect Awaking "
         target="T11">
1417 <graphics/>
1418 <inscription>
1419 <value>Default,1</value>
1420 <graphics/>
1421 </inscription>
1422 <tagged>
1423 <value>false</value>
1424 </tagged>
1425 <type value="normal"/>
1426 </arc>
1427 <arc id="Fall or stumble
         Detection  to T10" source="
         Fall or stumble  Detection "
         target="T10">
1428 <graphics/>
1429 <inscription>
1430 <value>Default,1</value>
1431 <graphics/>
1432 </inscription>
1433 <tagged>
1434 <value>false</value>
1435 </tagged>
1436 <type value="normal"/>
1437 </arc>
1438 <arc id="Family Confirmation  to
         T22" source="Family
         Confirmation " target="T22">
1439 <graphics/>
1440 <inscription>
1441 <value>Default,1</value>
1442 <graphics/>
1443 </inscription>
1444 <tagged>
1445 <value>false</value>
1446 </tagged>
1447 <type value="normal"/>
1448 </arc>
1449 <arc id="Family Confirmation  to
         T23" source="Family
         Confirmation " target="T23">
1450 <graphics/>
1451 <inscription>
1452 <value/>
1453 <graphics/>
1454 </inscription>
1455 <tagged>
1456 <value/>
1457 </tagged>
1458 <type value="inhibitor"/>
1459 </arc>
1460 <arc id="Family Notification  to
         T4" source="Family
         Notification " target="T4">
1461 <graphics/>
1462 <inscription>
1463 <value>Default,1</value>
1464 <graphics/>
1465 </inscription>
1466 <tagged>
1467 <value>false</value>
```

```
1468 </tagged>
1469 <type value="normal"/>
1470 </arc>
1471 <arc id="Gycemia Monitor  to T8"
        source="Gycemia Monitor "
        target="T8">
1472 <graphics/>
1473 <inscription>
1474 <value>Default,1</value>
1475 <graphics/>
1476 </inscription>
1477 <tagged>
1478 <value>false</value>
1479 </tagged>
1480 <type value="normal"/>
1481 </arc>
1482 <arc id="Light Control  to T11"
        source="Light Control " target
        ="T11">
1483 <graphics/>
1484 <inscription>
1485 <value>Default,1</value>
1486 <graphics/>
1487 </inscription>
1488 <tagged>
1489 <value>false</value>
1490 </tagged>
1491 <type value="normal"/>
1492 </arc>
1493 <arc id="Monitor (BP)  to T6"
        source="Monitor (BP) " target=
        "T6">
1494 <graphics/>
1495 <inscription>
1496 <value>Default,1</value>
1497 <graphics/>
1498 </inscription>
1499 <tagged>
1500 <value>false</value>
1501 </tagged>
1502 <type value="normal"/>
1503 </arc>
1504 <arc id="Monitor (BR)  to T7"
        source="Monitor (BR) " target=
        "T7">
1505 <graphics/>
1506 <inscription>
1507 <value>Default,1</value>
1508 <graphics/>
1509 </inscription>
1510 <tagged>
1511 <value>false</value>
1512 </tagged>
1513 <type value="normal"/>
1514 </arc>
1515 <arc id="Monitor (BT)  to T9"
        source="Monitor (BT) " target=
        "T9">
1516 <graphics/>
1517 <inscription>
1518 <value>Default,1</value>
1519 <graphics/>
1520 </inscription>
1521 <tagged>
1522 <value>false</value>
1523 </tagged>
1524 <type value="normal"/>
1525 </arc>
1526 <arc id="Monitor night sleep and
        vital signs   to T26" source=
        "Monitor night sleep and vital
         signs  " target="T26">
1527 <graphics/>
1528 <inscription>
1529 <value>Default,1</value>
1530 <graphics/>
1531 </inscription>
1532 <tagged>
1533 <value>false</value>
1534 </tagged>
1535 <type value="normal"/>
1536 </arc>
1537 <arc id="Monitor Night Sleep  to
        T12" source="Monitor Night
        Sleep " target="T12">
1538 <graphics/>
1539 <inscription>
1540 <value>Default,1</value>
1541 <graphics/>
1542 </inscription>
1543 <tagged>
1544 <value>false</value>
1545 </tagged>
1546 <type value="normal"/>
```

```
1547 </arc>
1548 <arc id="Monitor Vital Signs    to
        T0" source="Monitor Vital
        Signs  " target="T0">
1549 <graphics/>
1550 <inscription>
1551 <value>Default,1</value>
1552 <graphics/>
1553 </inscription>
1554 <tagged>
1555 <value>false</value>
1556 </tagged>
1557 <type value="normal"/>
1558 </arc>
1559 <arc id="Notification system  to
        Broadcast of message" source="
        Notification system " target="
        Broadcast of message">
1560 <graphics/>
1561 <inscription>
1562 <value>Default,1</value>
1563 <graphics/>
1564 </inscription>
1565 <tagged>
1566 <value>false</value>
1567 </tagged>
1568 <type value="normal"/>
1569 </arc>
1570 <arc id="Patient Confirmation  to
        T16" source="Patient
        Confirmation " target="T16">
1571 <graphics/>
1572 <inscription>
1573 <value>Default,1</value>
1574 <graphics/>
1575 </inscription>
1576 <tagged>
1577 <value>false</value>
1578 </tagged>
1579 <type value="normal"/>
1580 </arc>
1581 <arc id="Patient Confirmation  to
        T17" source="Patient
        Confirmation " target="T17">
1582 <graphics/>
1583 <inscription>
1584 <value/>
1585 <graphics/>
1586 </inscription>
1587 <tagged>
1588 <value/>
1589 </tagged>
1590 <type value="inhibitor"/>
1591 </arc>
1592 <arc id="Patient Confirm  to T15"
        source="Patient Confirm "
        target="T15">
1593 <graphics/>
1594 <inscription>
1595 <value>Default,1</value>
1596 <graphics/>
1597 </inscription>
1598 <tagged>
1599 <value>false</value>
1600 </tagged>
1601 <type value="normal"/>
1602 </arc>
1603 <arc id="Physician Confirmation
        to T24" source="Physician
        Confirmation " target="T24">
1604 <graphics/>
1605 <inscription>
1606 <value>Default,1</value>
1607 <graphics/>
1608 </inscription>
1609 <tagged>
1610 <value>false</value>
1611 </tagged>
1612 <type value="normal"/>
1613 </arc>
1614 <arc id="Physician Confirmation
        to T25" source="Physician
        Confirmation " target="T25">
1615 <graphics/>
1616 <inscription>
1617 <value/>
1618 <graphics/>
1619 </inscription>
1620 <tagged>
1621 <value/>
1622 </tagged>
1623 <type value="inhibitor"/>
1624 </arc>
```

```
1625 <arc id="Physician Notification
        to T5" source="Physician
        Notification " target="T5">
1626 <graphics/>
1627 <inscription>
1628 <value>Default,1</value>
1629 <graphics/>
1630 </inscription>
1631 <tagged>
1632 <value>false</value>
1633 </tagged>
1634 <type value="normal"/>
1635 </arc>
1636 <arc id="Reminder message to
        Notification system " source="
        Reminder message" target="
        Notification system ">
1637 <graphics/>
1638 <inscription>
1639 <value>Default,1</value>
1640 <graphics/>
1641 </inscription>
1642 <tagged>
1643 <value>false</value>
1644 </tagged>
1645 <type value="normal"/>
1646 </arc>
1647 <arc id="Reminder to T3" source="
        Reminder" target="T3">
1648 <graphics/>
1649 <inscription>
1650 <value>Default,1</value>
1651 <graphics/>
1652 </inscription>
1653 <tagged>
1654 <value>false</value>
1655 </tagged>
1656 <type value="normal"/>
1657 </arc>
1658 <arc id="T0 to Monitor night sleep
         and vital signs  " source="
        T0" target="Monitor night
        sleep and vital signs   ">
1659 <graphics/>
1660 <inscription>
1661 <value>Default,1</value>
1662 <graphics/>
1663 </inscription>
1664 <tagged>
1665 <value>false</value>
1666 </tagged>
1667 <type value="normal"/>
1668 </arc>
1669 <arc id="T10 to Automated Activity
         and Fall Detection  " source=
        "T10" target="Automated
        Activity and Fall Detection  "
        >
1670 <graphics/>
1671 <inscription>
1672 <value>Default,1</value>
1673 <graphics/>
1674 </inscription>
1675 <tagged>
1676 <value>false</value>
1677 </tagged>
1678 <type value="normal"/>
1679 </arc>
1680 <arc id="T11 to Automated Activity
         and Fall Detection  " source=
        "T11" target="Automated
        Activity and Fall Detection  "
        >
1681 <graphics/>
1682 <inscription>
1683 <value>Default,1</value>
1684 <graphics/>
1685 </inscription>
1686 <tagged>
1687 <value>false</value>
1688 </tagged>
1689 <type value="normal"/>
1690 </arc>
1691 <arc id="T12 to Automated Activity
         and Fall Detection  " source=
        "T12" target="Automated
        Activity and Fall Detection  "
        >
1692 <graphics/>
1693 <inscription>
1694 <value>Default,1</value>
1695 <graphics/>
1696 </inscription>
1697 <tagged>
```

```
1698 <value>false</value>
1699 </tagged>
1700 <type value="normal"/>
1701 </arc>
1702 <arc id="T13 to Detect Awaking "
         source="T13" target="Detect
         Awaking ">
1703 <graphics/>
1704 <inscription>
1705 <value>Default,1</value>
1706 <graphics/>
1707 </inscription>
1708 <tagged>
1709 <value>false</value>
1710 </tagged>
1711 <type value="normal"/>
1712 </arc>
1713 <arc id="T14 to Monitor Night
         Sleep " source="T14" target="
         Monitor Night Sleep ">
1714 <graphics/>
1715 <inscription>
1716 <value>Default,1</value>
1717 <graphics/>
1718 </inscription>
1719 <tagged>
1720 <value>false</value>
1721 </tagged>
1722 <type value="normal"/>
1723 </arc>
1724 <arc id="T15 to Reminder" source="
         T15" target="Reminder">
1725 <graphics/>
1726 <inscription>
1727 <value>Default,1</value>
1728 <graphics/>
1729 </inscription>
1730 <tagged>
1731 <value>false</value>
1732 </tagged>
1733 <type value="normal"/>
1734 </arc>
1735 <arc id="T16 to Patient Confirm "
         source="T16" target="Patient
         Confirm ">
1736 <graphics/>
1737 <inscription>
1738 <value>Default,1</value>
1739 <graphics/>
1740 </inscription>
1741 <tagged>
1742 <value>false</value>
1743 </tagged>
1744 <type value="normal"/>
1745 </arc>
1746 <arc id="T17 to Patient Confirm "
         source="T17" target="Patient
         Confirm ">
1747 <graphics/>
1748 <inscription>
1749 <value>Default,1</value>
1750 <graphics/>
1751 </inscription>
1752 <tagged>
1753 <value>false</value>
1754 </tagged>
1755 <type value="normal"/>
1756 </arc>
1757 <arc id="T18 to Wait for Caregiver
          confirmation " source="T18"
         target="Wait for Caregiver
         confirmation ">
1758 <graphics/>
1759 <inscription>
1760 <value>Default,1</value>
1761 <graphics/>
1762 </inscription>
1763 <tagged>
1764 <value>false</value>
1765 </tagged>
1766 <type value="normal"/>
1767 </arc>
1768 <arc id="T18 to Wait for Family
         confirmation " source="T18"
         target="Wait for Family
         confirmation ">
1769 <graphics/>
1770 <inscription>
1771 <value>Default,1</value>
1772 <graphics/>
1773 </inscription>
1774 <tagged>
1775 <value>false</value>
1776 </tagged>
```

```
1777 <type value="normal"/>
1778 </arc>
1779 <arc id="T18 to Wait for Patient
        confirmation " source="T18"
        target="Wait for Patient
        confirmation ">
1780 <graphics/>
1781 <inscription>
1782 <value>Default,1</value>
1783 <graphics/>
1784 </inscription>
1785 <tagged>
1786 <value>false</value>
1787 </tagged>
1788 <type value="normal"/>
1789 </arc>
1790 <arc id="T18 to Wait for Physician
         confirmation " source="T18"
        target="Wait for Physician
        confirmation ">
1791 <graphics/>
1792 <inscription>
1793 <value>Default,1</value>
1794 <graphics/>
1795 </inscription>
1796 <tagged>
1797 <value>false</value>
1798 </tagged>
1799 <type value="normal"/>
1800 </arc>
1801 <arc id="T1 to Monitor night sleep
         and vital signs  " source="
        T1" target="Monitor night
        sleep and vital signs  ">
1802 <graphics/>
1803 <inscription>
1804 <value>Default,1</value>
1805 <graphics/>
1806 </inscription>
1807 <tagged>
1808 <value>false</value>
1809 </tagged>
1810 <type value="normal"/>
1811 </arc>
1812 <arc id="T20 to Alert Confirm "
        source="T20" target="Alert
        Confirm ">
1813 <graphics/>
1814 <inscription>
1815 <value>Default,1</value>
1816 <graphics/>
1817 </inscription>
1818 <tagged>
1819 <value>false</value>
1820 </tagged>
1821 <type value="normal"/>
1822 </arc>
1823 <arc id="T21 to Alert Confirm "
        source="T21" target="Alert
        Confirm ">
1824 <graphics/>
1825 <inscription>
1826 <value>Default,1</value>
1827 <graphics/>
1828 </inscription>
1829 <tagged>
1830 <value>false</value>
1831 </tagged>
1832 <type value="normal"/>
1833 </arc>
1834 <arc id="T22 to Alert Confirm "
        source="T22" target="Alert
        Confirm ">
1835 <graphics/>
1836 <inscription>
1837 <value>Default,1</value>
1838 <graphics/>
1839 </inscription>
1840 <tagged>
1841 <value>false</value>
1842 </tagged>
1843 <type value="normal"/>
1844 </arc>
1845 <arc id="T23 to Alert Confirm "
        source="T23" target="Alert
        Confirm ">
1846 <graphics/>
1847 <inscription>
1848 <value>Default,1</value>
1849 <graphics/>
1850 </inscription>
1851 <tagged>
1852 <value>false</value>
1853 </tagged>
```

```
1854 <type value="normal"/>
1855 </arc>
1856 <arc id="T24 to Alert Confirm "
         source="T24" target="Alert
         Confirm ">
1857 <graphics/>
1858 <inscription>
1859 <value>Default,1</value>
1860 <graphics/>
1861 </inscription>
1862 <tagged>
1863 <value>false</value>
1864 </tagged>
1865 <type value="normal"/>
1866 </arc>
1867 <arc id="T25 to Alert Confirm "
         source="T25" target="Alert
         Confirm ">
1868 <graphics/>
1869 <inscription>
1870 <value>Default,1</value>
1871 <graphics/>
1872 </inscription>
1873 <tagged>
1874 <value>false</value>
1875 </tagged>
1876 <type value="normal"/>
1877 </arc>
1878 <arc id="T26 to Bed Sensors
         Monitor " source="T26" target=
         "Bed Sensors Monitor ">
1879 <graphics/>
1880 <inscription>
1881 <value>Default,1</value>
1882 <graphics/>
1883 </inscription>
1884 <tagged>
1885 <value>false</value>
1886 </tagged>
1887 <type value="normal"/>
1888 </arc>
1889 <arc id="T26 to Caregiver
         Confirmation " source="T26"
         target="Caregiver
         Confirmation ">
1890 <graphics/>
1891 <inscription>
1892 <value>Default,1</value>
1893 <graphics/>
1894 </inscription>
1895 <tagged>
1896 <value>false</value>
1897 </tagged>
1898 <type value="normal"/>
1899 </arc>
1900 <arc id="T26 to CPAP Monitor "
         source="T26" target="CPAP
         Monitor ">
1901 <graphics/>
1902 <inscription>
1903 <value>Default,1</value>
1904 <graphics/>
1905 </inscription>
1906 <tagged>
1907 <value>false</value>
1908 </tagged>
1909 <type value="normal"/>
1910 </arc>
1911 <arc id="T26 to Fall or stumble
         Detection " source="T26"
         target="Fall or stumble
         Detection ">
1912 <graphics/>
1913 <inscription>
1914 <value>Default,1</value>
1915 <graphics/>
1916 </inscription>
1917 <tagged>
1918 <value>false</value>
1919 </tagged>
1920 <type value="normal"/>
1921 </arc>
1922 <arc id="T26 to Family
         Confirmation " source="T26"
         target="Family Confirmation ">
1923 <graphics/>
1924 <inscription>
1925 <value>Default,1</value>
1926 <graphics/>
1927 </inscription>
1928 <tagged>
1929 <value>false</value>
1930 </tagged>
1931 <type value="normal"/>
```

```
1932 </arc>
1933 <arc id="T26 to Gycemia Monitor "
         source="T26" target="Gycemia
         Monitor ">
1934 <graphics/>
1935 <inscription>
1936 <value>Default,1</value>
1937 <graphics/>
1938 </inscription>
1939 <tagged>
1940 <value>false</value>
1941 </tagged>
1942 <type value="normal"/>
1943 </arc>
1944 <arc id="T26 to Light Control "
         source="T26" target="Light
         Control ">
1945 <graphics/>
1946 <inscription>
1947 <value>Default,1</value>
1948 <graphics/>
1949 </inscription>
1950 <tagged>
1951 <value>false</value>
1952 </tagged>
1953 <type value="normal"/>
1954 </arc>
1955 <arc id="T26 to Monitor (BP) "
         source="T26" target="Monitor (
         BP) ">
1956 <graphics/>
1957 <inscription>
1958 <value>Default,1</value>
1959 <graphics/>
1960 </inscription>
1961 <tagged>
1962 <value>false</value>
1963 </tagged>
1964 <type value="normal"/>
1965 </arc>
1966 <arc id="T26 to Monitor (BR) "
         source="T26" target="Monitor (
         BR) ">
1967 <graphics/>
1968 <inscription>
1969 <value>Default,1</value>
1970 <graphics/>
1971 </inscription>
1972 <tagged>
1973 <value>false</value>
1974 </tagged>
1975 <type value="normal"/>
1976 </arc>
1977 <arc id="T26 to Monitor (BT) "
         source="T26" target="Monitor (
         BT) ">
1978 <graphics/>
1979 <inscription>
1980 <value>Default,1</value>
1981 <graphics/>
1982 </inscription>
1983 <tagged>
1984 <value>false</value>
1985 </tagged>
1986 <type value="normal"/>
1987 </arc>
1988 <arc id="T26 to Patient
         Confirmation " source="T26"
         target="Patient Confirmation "
         >
1989 <graphics/>
1990 <inscription>
1991 <value>Default,1</value>
1992 <graphics/>
1993 </inscription>
1994 <tagged>
1995 <value>false</value>
1996 </tagged>
1997 <type value="normal"/>
1998 </arc>
1999 <arc id="T26 to Physician
         Confirmation " source="T26"
         target="Physician Confirmation
          ">
2000 <graphics/>
2001 <inscription>
2002 <value>Default,1</value>
2003 <graphics/>
2004 </inscription>
2005 <tagged>
2006 <value>false</value>
2007 </tagged>
2008 <type value="normal"/>
2009 </arc>
```

```
2010 <arc id="T26 to Reminder message"
        source="T26" target="Reminder
        message">
2011 <graphics/>
2012 <inscription>
2013 <value>Default,1</value>
2014 <graphics/>
2015 </inscription>
2016 <tagged>
2017 <value>false</value>
2018 </tagged>
2019 <type value="normal"/>
2020 </arc>
2021 <arc id="T2 to Monitor night sleep
        and vital signs  " source="
        T2" target="Monitor night
        sleep and vital signs  ">
2022 <graphics/>
2023 <inscription>
2024 <value>Default,1</value>
2025 <graphics/>
2026 </inscription>
2027 <tagged>
2028 <value>false</value>
2029 </tagged>
2030 <type value="normal"/>
2031 </arc>
2032 <arc id="T3 to Monitor night sleep
        and vital signs  " source="
        T3" target="Monitor night
        sleep and vital signs  ">
2033 <graphics/>
2034 <inscription>
2035 <value>Default,1</value>
2036 <graphics/>
2037 </inscription>
2038 <tagged>
2039 <value>false</value>
2040 </tagged>
2041 <type value="normal"/>
2042 </arc>
2043 <arc id="T4 to Automated Emergency
        Call  " source="T4" target="
        Automated Emergency Call  ">
2044 <graphics/>
2045 <inscription>
2046 <value>Default,1</value>
2047 <graphics/>
2048 </inscription>
2049 <tagged>
2050 <value>false</value>
2051 </tagged>
2052 <type value="normal"/>
2053 </arc>
2054 <arc id="T5 to Automated Emergency
        Call  " source="T5" target="
        Automated Emergency Call  ">
2055 <graphics/>
2056 <inscription>
2057 <value>Default,1</value>
2058 <graphics/>
2059 </inscription>
2060 <tagged>
2061 <value>false</value>
2062 </tagged>
2063 <type value="normal"/>
2064 </arc>
2065 <arc id="T6 to Caregiver
        Notification " source="T6"
        target="Caregiver Notification
         ">
2066 <graphics/>
2067 <inscription>
2068 <value>Default,1</value>
2069 <graphics/>
2070 </inscription>
2071 <tagged>
2072 <value>false</value>
2073 </tagged>
2074 <type value="normal"/>
2075 </arc>
2076 <arc id="T6 to Family Notification
        " source="T6" target="Family
        Notification ">
2077 <graphics/>
2078 <inscription>
2079 <value>Default,1</value>
2080 <graphics/>
2081 </inscription>
2082 <tagged>
2083 <value>false</value>
2084 </tagged>
2085 <type value="normal"/>
2086 </arc>
```

```
2087 <arc id="T6 to Monitor Vital Signs
         " source="T6" target="
     Monitor Vital Signs   ">
2088 <graphics/>
2089 <inscription>
2090 <value>Default,1</value>
2091 <graphics/>
2092 </inscription>
2093 <tagged>
2094 <value>false</value>
2095 </tagged>
2096 <type value="normal"/>
2097 </arc>
2098 <arc id="T6 to Physician
     Notification " source="T6"
     target="Physician Notification
      ">
2099 <graphics/>
2100 <inscription>
2101 <value>Default,1</value>
2102 <graphics/>
2103 </inscription>
2104 <tagged>
2105 <value>false</value>
2106 </tagged>
2107 <type value="normal"/>
2108 </arc>
2109 <arc id="T7 to Caregiver
     Notification " source="T7"
     target="Caregiver Notification
      ">
2110 <graphics/>
2111 <inscription>
2112 <value>Default,1</value>
2113 <graphics/>
2114 </inscription>
2115 <tagged>
2116 <value>false</value>
2117 </tagged>
2118 <type value="normal"/>
2119 </arc>
2120 <arc id="T7 to Family Notification
      " source="T7" target="Family
     Notification ">
2121 <graphics/>
2122 <inscription>
2123 <value>Default,1</value>
2124 <graphics/>
2125 </inscription>
2126 <tagged>
2127 <value>false</value>
2128 </tagged>
2129 <type value="normal"/>
2130 </arc>
2131 <arc id="T7 to Monitor Vital Signs
         " source="T7" target="
     Monitor Vital Signs   ">
2132 <graphics/>
2133 <inscription>
2134 <value>Default,1</value>
2135 <graphics/>
2136 </inscription>
2137 <tagged>
2138 <value>false</value>
2139 </tagged>
2140 <type value="normal"/>
2141 </arc>
2142 <arc id="T7 to Physician
     Notification " source="T7"
     target="Physician Notification
      ">
2143 <graphics/>
2144 <inscription>
2145 <value>Default,1</value>
2146 <graphics/>
2147 </inscription>
2148 <tagged>
2149 <value>false</value>
2150 </tagged>
2151 <type value="normal"/>
2152 </arc>
2153 <arc id="T8 to Caregiver
     Notification " source="T8"
     target="Caregiver Notification
      ">
2154 <graphics/>
2155 <inscription>
2156 <value>Default,1</value>
2157 <graphics/>
2158 </inscription>
2159 <tagged>
2160 <value>false</value>
2161 </tagged>
2162 <type value="normal"/>
```

```
2163 </arc>
2164 <arc id="T8 to Family Notification
        " source="T8" target="Family
        Notification ">
2165 <graphics/>
2166 <inscription>
2167 <value>Default,1</value>
2168 <graphics/>
2169 </inscription>
2170 <tagged>
2171 <value>false</value>
2172 </tagged>
2173 <type value="normal"/>
2174 </arc>
2175 <arc id="T8 to Monitor Vital Signs
        " source="T8" target="
        Monitor Vital Signs  ">
2176 <graphics/>
2177 <inscription>
2178 <value>Default,1</value>
2179 <graphics/>
2180 </inscription>
2181 <tagged>
2182 <value>false</value>
2183 </tagged>
2184 <type value="normal"/>
2185 </arc>
2186 <arc id="T8 to Physician
        Notification " source="T8"
        target="Physician Notification
         ">
2187 <graphics/>
2188 <inscription>
2189 <value>Default,1</value>
2190 <graphics/>
2191 </inscription>
2192 <tagged>
2193 <value>false</value>
2194 </tagged>
2195 <type value="normal"/>
2196 </arc>
2197 <arc id="T9 to Caregiver
        Notification " source="T9"
        target="Caregiver Notification
         ">
2198 <graphics/>
2199 <inscription>
2200 <value>Default,1</value>
2201 <graphics/>
2202 </inscription>
2203 <tagged>
2204 <value>false</value>
2205 </tagged>
2206 <type value="normal"/>
2207 </arc>
2208 <arc id="T9 to Family Notification
        " source="T9" target="Family
        Notification ">
2209 <graphics/>
2210 <inscription>
2211 <value>Default,1</value>
2212 <graphics/>
2213 </inscription>
2214 <tagged>
2215 <value>false</value>
2216 </tagged>
2217 <type value="normal"/>
2218 </arc>
2219 <arc id="T9 to Monitor Vital Signs
        " source="T9" target="
        Monitor Vital Signs  ">
2220 <graphics/>
2221 <inscription>
2222 <value>Default,1</value>
2223 <graphics/>
2224 </inscription>
2225 <tagged>
2226 <value>false</value>
2227 </tagged>
2228 <type value="normal"/>
2229 </arc>
2230 <arc id="T9 to Physician
        Notification " source="T9"
        target="Physician Notification
         ">
2231 <graphics/>
2232 <inscription>
2233 <value>Default,1</value>
2234 <graphics/>
2235 </inscription>
2236 <tagged>
2237 <value>false</value>
2238 </tagged>
2239 <type value="normal"/>
```

```
2240 </arc>
2241 <arc id="Wait for Caregiver
         confirmation  to T20" source="
         Wait for Caregiver
         confirmation " target="T20">
2242 <graphics/>
2243 <inscription>
2244 <value>Default,1</value>
2245 <graphics/>
2246 </inscription>
2247 <tagged>
2248 <value>false</value>
2249 </tagged>
2250 <type value="normal"/>
2251 </arc>
2252 <arc id="Wait for Caregiver
         confirmation  to T21" source="
         Wait for Caregiver
         confirmation " target="T21">
2253 <graphics/>
2254 <inscription>
2255 <value>Default,1</value>
2256 <graphics/>
2257 </inscription>
2258 <tagged>
2259 <value>false</value>
2260 </tagged>
2261 <type value="normal"/>
2262 </arc>
2263 <arc id="Wait for Family
         confirmation  to T22" source="
         Wait for Family confirmation "
          target="T22">
2264 <graphics/>
2265 <inscription>
2266 <value>Default,1</value>
2267 <graphics/>
2268 </inscription>
2269 <tagged>
2270 <value>false</value>
2271 </tagged>
2272 <type value="normal"/>
2273 </arc>
2274 <arc id="Wait for Family
         confirmation  to T23" source="
         Wait for Family confirmation "
          target="T23">
2275 <graphics/>
2276 <inscription>
2277 <value>Default,1</value>
2278 <graphics/>
2279 </inscription>
2280 <tagged>
2281 <value>false</value>
2282 </tagged>
2283 <type value="normal"/>
2284 </arc>
2285 <arc id="Wait for Patient
         confirmation  to T16" source="
         Wait for Patient confirmation
         " target="T16">
2286 <graphics/>
2287 <inscription>
2288 <value>Default,1</value>
2289 <graphics/>
2290 </inscription>
2291 <tagged>
2292 <value>false</value>
2293 </tagged>
2294 <type value="normal"/>
2295 </arc>
2296 <arc id="Wait for Patient
         confirmation  to T17" source="
         Wait for Patient confirmation
         " target="T17">
2297 <graphics/>
2298 <inscription>
2299 <value>Default,1</value>
2300 <graphics/>
2301 </inscription>
2302 <tagged>
2303 <value>false</value>
2304 </tagged>
2305 <type value="normal"/>
2306 </arc>
2307 <arc id="Wait for Physician
         confirmation  to T25" source="
         Wait for Physician
         confirmation " target="T25">
2308 <graphics/>
2309 <inscription>
2310 <value>Default,1</value>
2311 <graphics/>
2312 </inscription>
```

```
2313 <tagged>
2314 <value>false</value>
2315 </tagged>
2316 <type value="normal"/>
2317 </arc>
2318 </net>
2319 </pnml>
```

APPENDIX

F

PYTHON CODE FOR KML<–>PNML TRANSFER

```python
 1
 2  import pandas as pd
 3  import xml.etree.ElementTree as ET
 4
 5  import
        funtionCalculateQuantifyTransition
         as CQT
 6  import funtionWriteXml as WXml
 7  import funtionWritePnml as WPnml
 8  import funtionWriteFileXml as
        WFXml
 9
10  from xml.etree.ElementTree import
        parse
11  document = parse('Light_Control.
        kml')
12  root = document.getroot()
13
14  # Define the classes.
15  class GOAL:
16      def __init__(self, id, name,
        type, positionX, positionY):
17          self.id = id
18          self.name = name
19          self.type = type
20          self.positionX = positionX
21          self.positionY = positionY
22
23      def goal_Id(self):
24          return self.id
25
26      def goal_Name(self):
27          return self.name
28
29      def goal_Type(self):
30          return self.type
31
32      def goal_PositionX(self):
33          return self.positionX
34
35      def goal_PositionY(self):
36          return self.positionY
37
38  class OPERATION:
39      def __init__(self, id,
        precondition, postcondition,
        type, positionX, positionY):
40          self.id = id
41          self.precondition =
        precondition
42          self.postcondition =
        postcondition
43          self.type = type
44          self.positionX = positionX
45          self.positionY = positionY
46
47      def operation_Id(self):
48          return self.id
49
50      def operation_Precondition(
        self):
51          return self.precondition
52
```

```
53    def operation_Postcondition(        98
      self):                             99  list_Goal              = list()
54        return self.postcondition     100  lst_Id_Goal            = list()
55                                       101  list_Operation         = list()
56    def operation_Type(self):          102  lst_Id_Operation       = list()
57        return self.type               103  list_Object            = list()
58                                       104  list_Responsability    = list()
59    def operation_PositionX(self):     105
60        return self.positionX          106  input_Vector_List      = []
61                                       107  list_Connection        = []
62    def operation_PositionY(self):     108  list_Type              = []
63        return self.positionY          109  list_Transition        = []
64                                       110  output_Vector_List     = []
65  # Initialize the empty lists of      111
        each tag.                        112  # FOR to iterate through each
66  Model              = []                      element, find the first
67  Id                 = []                      children and take their values
68  Name               = []                      . For those who are children
69  Type               = []                      of children add an empty space
70  Pattern            = []                      , because you can not access
71  Class              = []                      them.
72  Precondition       = []              113  for item in document.iterfind('
73  Postcondition      = []                      Element'):
74                                       114      Model.append(item.findtext('
75  ToRefineAnd        = []                      Model'))
76  InRefineAnd        = []              115      Id.append(item.findtext('Id'))
77  ToRefineOr         = []              116      Name.append(item.findtext('
78  InRefineOr         = []                      Name'))
79  ConflictTo         = []              117      Type.append(item.findtext('
80  Resolution         = []                      Type'))
81  Obstrution         = []              118      Pattern.append(item.findtext('
82  ExpectationOf      = []                      Pattern'))
83  ConcernsTo         = []              119      Class.append(item.findtext('
84  AssociateTo        = []                      Class'))
85  IsA                = []              120      Precondition.append(item.
86  AssignedTo         = []                      findtext('Precondition'))
87  ResponsabilityOf   = []              121      Postcondition.append(item.
88  CauseTo            = []                      findtext('Postcondition'))
89  InputTo            = []              122
90  OutputTo           = []              123      ToRefineAnd.append('NONE')
91  PerformanceOf      = []              124      InRefineAnd.append('NONE')
92  OperationalizationOf = []            125      ToRefineOr.append('NONE')
93                                       126      InRefineOr.append('NONE')
94  Height             = []              127      ConflictTo.append('NONE')
95  Widtht             = []              128      Resolution.append('NONE')
96  PositionX          = []              129      Obstrution.append('NONE')
97  PositionY          = []              130      ExpectationOf.append('NONE')
```

```
131        ConcernsTo.append('NONE')
132        AssociateTo.append('NONE')
133        IsA.append('NONE')
134        AssignedTo.append('NONE')
135        ResponsabilityOf.append('NONE'
           )
136        CauseTo.append('NONE')
137        InputTo.append('NONE')
138        OutputTo.append('NONE')
139        PerformanceOf.append('NONE')
140        OperationalizationOf.append('
           NONE')
141
142        Height.append('NONE')
143        Widtht.append('NONE')
144        PositionX.append('NONE')
145        PositionY.append('NONE')
146
147 # Create an auxiliary variable
       that allows us to store the
       value of the tag in the
       appropriate position.
148 aux_Len = 0
149 for nodo in root.iter('Refinements
       '):
150    for elemento in nodo.iter():
151        if elemento.tag == '
           ToRefineAnd':
152            ToRefineAnd[aux_Len] =
            elemento.text
153        if elemento.tag == '
           InRefineAnd':
154            InRefineAnd[aux_Len] =
            elemento.text
155        if elemento.tag == '
           ToRefineOr':
156            ToRefineOr[aux_Len] =
           elemento.text
157        if elemento.tag == '
           InRefineOr':
158            InRefineOr[aux_Len] =
           elemento.text
159        if elemento.tag == '
           ConflictTo':
160            ConflictTo[aux_Len] =
           elemento.text
161        if elemento.tag == '
           Resolution':
162            Resolution[aux_Len] =
           elemento.text
163        if elemento.tag == '
           Obstrution':
164            Obstrution[aux_Len] =
           elemento.text
165        if elemento.tag == '
           ExpectationOf':
166            ExpectationOf[aux_Len]
            = elemento.text
167        if elemento.tag == '
           ConcernsTo':
168            ConcernsTo[aux_Len] =
           elemento.text
169        if elemento.tag == '
           AssociateTo':
170            AssociateTo[aux_Len] =
            elemento.text
171        if elemento.tag == 'IsA':
172            IsA[aux_Len] =
           elemento.text
173        if elemento.tag == '
           AssignedTo':
174            AssignedTo[aux_Len] =
           elemento.text
175        if elemento.tag == '
           ResponsabilityOf':
176            ResponsabilityOf[
           aux_Len] = elemento.text
177        if elemento.tag == '
           CauseTo':
178            CauseTo[aux_Len] =
           elemento.text
179        if elemento.tag == '
           InputTo':
180            InputTo[aux_Len] =
           elemento.text
181        if elemento.tag == '
           OutputTo':
182            OutputTo[aux_Len] =
           elemento.text
183        if elemento.tag == '
           PerformanceOf':
184            PerformanceOf[aux_Len]
            = elemento.text
```

```
185        if elemento.tag == '
    Operationalizationof':
186             OperationalizationOf[
    aux_Len] = elemento.text
187        aux_Len = aux_Len + 1
188
189 aux_Len = 0
190 for nodo in root.iter('Graphics'):
191    for elemento in nodo.iter():
192        if elemento.tag == 'Height
    ':
193             Height[aux_Len] =
    elemento.text
194        if elemento.tag == 'Widtht
    ':
195             Widtht[aux_Len] =
    elemento.text
196        aux_Len = aux_Len + 1
197
198 aux_Len = 0
199 for nodo in root.iter('Position'):
200    for elemento in nodo.iter():
201        if elemento.tag == 'x':
202             PositionX[aux_Len] =
    elemento.text
203        if elemento.tag == 'y':
204             PositionY[aux_Len] =
    elemento.text
205        aux_Len = aux_Len + 1
206
207 # Main lists.
208 print('')
209 print('Id')
210 print(Id)
211 print('ToRefineAnd')
212 print(ToRefineAnd)
213 print('ToRefineOr')
214 print(ToRefineOr)
215 print('ExpectationOf')
216 print(ExpectationOf)
217 print('OperationalizationOf')
218 print(OperationalizationOf)
219 print('')
220
221 # Create the table.
222
223 df = pd.DataFrame({'Model':Model,
    'Id':Id, 'Name':Name, 'Type':
    Type, 'Pattern':Pattern, '
    Class':Class, 'Precondition':
    Precondition, 'Postcondition':
    Postcondition,'ToRefineAnd':
    ToRefineAnd, 'InRefineAnd':
    InRefineAnd, 'ToRefineOr':
    ToRefineOr, 'InRefineOr':
    InRefineOr, 'ConflictTo':
    ConflictTo, 'Resolution':
    Resolution, 'Obstrution':
    Obstrution, 'ExpectationOf':
    ExpectationOf, 'ConcernsTo':
    ConcernsTo, 'AssociateTo':
    AssociateTo, 'IsA':IsA, '
    AssignedTo':AssignedTo, '
    ResponsabilityOf':
    ResponsabilityOf, 'CauseTo':
    CauseTo, 'InputTo':InputTo, '
    OutputTo':OutputTo, 'OutputTo'
    :OutputTo, 'PerformanceOf':
    PerformanceOf, '
    OperationalizationOf':
    OperationalizationOf, 'Height'
    :Height, 'Widtht':Widtht, '
    PositionX':PositionX, '
    PositionY':PositionY})
224
225 # Print table df.
226 print(df)
227 print('')
228 print('Dados de prueba')
229 print()
230
231 # Created object.
232 df_Goal = df.where(df['Model']=='
    Goal')
233 df_Operation = df.where(df['Model'
    ]=='Operation')
234 df_Object = df.where(df['Model']==
    'Object')
235 df_Responsability = df.where(df['
    Model']=='Responsability')
236
237 for index, row in df_Goal.iterrows
    ():
```

```
238    if df_Goal.loc[index][0] == '
       Goal':
239        Goal = GOAL(row['Id'], row
       ['Name'], row['Type'], row['
       PositionX'], row['PositionY'])
240        list_Goal.append(Goal)
241
242 # For to create the new list with
       the IDs that are part of the
       Goal.
243 for index_lst_Id_Goal in range(len
       (list_Goal)):
244     lst_Id_Goal.append(list_Goal[
       index_lst_Id_Goal].goal_Id())
245
246 helper_For_Goal_Size = len(
       list_Goal)
247
248 for index, row in df_Operation.
       iterrows():
249    if df_Operation.loc[index][0]
       == 'Operation':
250        Operation = OPERATION(row[
       'Id'], row['Precondition'],
       row['Postcondition'], row['
       Type'], row['PositionX'], row[
       'PositionY'])
251        list_Operation.append(
       Operation)
252
253 # For to create the new list with
       the IDs that are part of the
       Operation.
254 for index_lst_Id_Operation in
       range(len(list_Operation)):
255     lst_Id_Operation.append(
       list_Operation[
       index_lst_Id_Operation].
       operation_Id())
256
257 # Calculate the number of
       transitions that must be
       generated in the goal.
258 cont_Transition = CQT.
       calculate_Quantify_Transition(
       lst_Id_Goal, ToRefineAnd,
       ToRefineOr, input_Vector_List,
```

```
       list_Connection, list_Type,
       list_Goal, list_Transition,
       output_Vector_List, Id,
       ExpectationOf)
259
260 # Generate the list only with Goal
261 df_Transition = pd.DataFrame({'
       Input Vector List':
       input_Vector_List, 'List
       Connection':list_Connection, '
       List Type':list_Type, 'List
       Transition':list_Transition, '
       Output Vector List':
       output_Vector_List})
262
263 print('')
264 print(df_Transition)
265
266 # Write .xml file
267 xml_pnml = ET.tostring(WXml.
       write_Xml())
268 pnml_pnml = ET.tostring(WPnml.
       write_Pnml(
       helper_For_Goal_Size,
       list_Goal, cont_Transition,
       input_Vector_List,
       output_Vector_List,
       list_Transition, lst_Id_Goal,
       ToRefineAnd, ToRefineOr,
       ExpectationOf,
       OperationalizationOf,
       list_Operation,
       list_Connection, list_Type, Id
       , lst_Id_Operation))
269
270 # Generate the list with Operation
271 df_Transition = pd.DataFrame({'
       Input Vector List':
       input_Vector_List, 'List
       Connection':list_Connection, '
       List Type':list_Type, 'List
       Transition':list_Transition, '
       Output Vector List':
       output_Vector_List})
272
273 print('')
274 print(df_Transition)
```

```
275
276 with open("Monitor_Night_Sleep.xml
       ", "wb") as f:
277     f.write(xml_pnml)
278     f.write(pnml_pnml)
279     f.close()
280
281 # Function to format the file
282 WFXml.write_File_Xml()
```

KML CODE FOR LIGHT CONTROL

```
1  <?kml version="1.0" encoding="ISO
      -8859-1"?>
2  <kml>
3  <Element>
4  <Model>Goal</Model>
5  <Id>2</Id>
6  <Name>Light Control</Name>
7  <Type>Goal</Type>
8  <Refinements>
9  <ToRefineOr>3;4</ToRefineOr>
10 </Refinements>
11 <Graphics>
12 <Height>40</Height>
13 <Widtht>146</Widtht>
14 <Position>
15 <x>638.0</x>
16 <y>20.0</y>
17 </Position>
18 </Graphics>
19 </Element>
20 <Element>
21 <Model>Goal</Model>
22 <Id>3</Id>
23 <Name>Bathroom lights</Name>
24 <Type>Requirement</Type>
25 <Pattern>Achieve</Pattern>
26 <Class>Functional</Class>
27 <Refinements>
28 <InRefineOr>2</InRefineOr>
29 <Operationalizationof>11</
      Operationalizationof>
30 </Refinements>
31 <Graphics>
32 <Height>40</Height>
33 <Widtht>146</Widtht>
34 <Position>
35 <x>505.0</x>
36 <y>134.0</y>
37 </Position>
38 </Graphics>
39 </Element>
40 <Element>
41 <Model>Goal</Model>
42 <Id>4</Id>
43 <Name>Room lights</Name>
44 <Type>Requirement</Type>
45 <Pattern>Achieve</Pattern>
46 <Class>Functional</Class>
47 <Refinements>
48 <InRefineOr>2</InRefineOr>
49 <Operationalizationof>12</
      Operationalizationof>
50 </Refinements>
51 <Graphics>
52 <Height>40</Height>
53 <Widtht>118</Widtht>
54 <Position>
55 <x>796.0</x>
56 <y>136.0</y>
57 </Position>
58 </Graphics>
59 </Element>
60 <Element>
```

```
 61 <Model>Operation</Model>                  103 <CauseTo>11;12</CauseTo>
 62 <Id>11</Id>                               104 </Refinements>
 63 <Name>Control bathroom lights</           105 <Graphics>
       Name>                                  106 <Height>43</Height>
 64 <Type>Operation</Type>                    107 <Widtht>96</Widtht>
 65 <Precondition>Bath_Lights_Off</           108 <Position>
       Precondition>                          109 <x>700.0</x>
 66 <Postcondition>Bath_Lights_On</           110 <y>216.0</y>
       Postcondition>                         111 </Position>
 67 <Refinements>                             112 </Graphics>
 68 </Refinements>                            113 </Element>
 69 <Graphics>                                114 <Element>
 70 <Height>49</Height>                       115 <Model>Object</Model>
 71 <Widtht>132</Widtht>                      116 <Id>14</Id>
 72 <Position>                                117 <Name>Bath Device
 73 <x>534.0</x>                              118 -------------------------
 74 <y>304.0</y>                              119 Pres_Sensor: off
 75 </Position>                               120 Light_Switch: off
 76 </Graphics>                               121 </Name>
 77 </Element>                                122 <Type>Entity</Type>
 78 <Element>                                 123 <Refinements>
 79 <Model>Operation</Model>                  124 <InputTo>11</InputTo>
 80 <Id>12</Id>                               125 <OutputTo>11</OutputTo>
 81 <Name>Control room lights                 126 </Refinements>
 82 </Name>                                   127 <Graphics>
 83 <Type>Operation</Type>                    128 <Height>76</Height>
 84 <Precondition>Room_Lights_Off</           129 <Widtht>111</Widtht>
       Precondition>                          130 <Position>
 85 <Postcondition>Room_Lights_On</           131 <x>368.0</x>
       Postcondition>                         132 <y>292.0</y>
 86 <Refinements>                             133 </Position>
 87 </Refinements>                            134 </Graphics>
 88 <Graphics>                                135 </Element>
 89 <Height>49</Height>                       136 <Element>
 90 <Widtht>98</Widtht>                       137 <Model>Object</Model>
 91 <Position>                                138 <Id>15</Id>
 92 <x>906.0</x>                              139 <Name>Room Device
 93 <y>301.0</y>                              140 ---------------------
 94 </Position>                               141 Pres_Sensor: off
 95 </Graphics>                               142 Light_Switch: off</Name>
 96 </Element>                                143 <Type>Entity</Type>
 97 <Element>                                 144 <Refinements>
 98 <Model>Operation</Model>                  145 <InputTo>12</InputTo>
 99 <Id>13</Id>                               146 <OutputTo>12</OutputTo>
100 <Name>Motion detection</Name>            147 </Refinements>
101 <Type>Event</Type>                        148 <Graphics>
102 <Refinements>                             149 <Height>69</Height>
```

```
150 <Widtht>101</Widtht>
151 <Position>
152 <x>730.0</x>
153 <y>314.0</y>
154 </Position>
155 </Graphics>
156 </Element>
157 <Element>
158 <Model>Responsability</Model>
159 <Id>16</Id>
160 <Name>B_Light Control System</Name
        >
161 <Type>Agent</Type>
162 <Class>System Agent</Class>
163 <Refinements>
164 <Performanceof>11</Performanceof>
165 </Refinements>
166 <Graphics>
167 <Height>41</Height>
168 <Widtht>142</Widtht>
169 <Position>
170 <x>458.0</x>
171 <y>414.0</y>
172 </Position>
173 </Graphics>
174 </Element>
175 <Element>
176 <Model>Responsability</Model>
177 <Id>30</Id>
178 <Name>R_Light Control System</Name
        >
179 <Type>Agent</Type>
180 <Class>System Agent</Class>
181 <Refinements>
182 <Performanceof>12</Performanceof>
183 </Refinements>
184 <Graphics>
185 <Height>45</Height>
186 <Widtht>146</Widtht>
187 <Position>
188 <x>987.0</x>
189 <y>388.0</y>
190 </Position>
191 </Graphics>
192 </Element>
193 </kml>
```

PNML CODE FOR LIGHT CONTROL

```
1  <?xml version="1.0" encoding="ISO
       -8859-1"?><pnml>
2  <net id="Net-One" type="P/T net">
3  <token id="Default" enabled="true"
       red="0" green="0" blue="0"/>
4  <place id="Bath_Lights_Off">
5  <graphics>
6  <position x="240.0" y="90.0"/>
7  </graphics>
8  <name>
9  <value>Bath_Lights_Off</value>
10 <graphics>
11 <offset x="58.0" y="55.0"/>
12 </graphics>
13 </name>
14 <initialMarking>
15 <value>Default,0</value>
16 <graphics>
17 <offset x="0.0" y="0.0"/>
18 </graphics>
19 </initialMarking>
20 <capacity>
21 <value>0</value>
22 </capacity>
23 </place>
24 <place id="Bath_Lights_On">
25 <graphics>
26 <position x="375.0" y="90.0"/>
27 </graphics>
28 <name>
29 <value>Bath_Lights_On</value>
30 <graphics>
31 <offset x="63.0" y="59.0"/>
32 </graphics>
33 </name>
34 <initialMarking>
35 <value>Default,0</value>
36 <graphics>
37 <offset x="0.0" y="0.0"/>
38 </graphics>
39 </initialMarking>
40 <capacity>
41 <value>0</value>
42 </capacity>
43 </place>
44 <place id="Bathroom lights ">
45 <graphics>
46 <position x="570.0" y="150.0"/>
47 </graphics>
48 <name>
49 <value>Bathroom lights </value>
50 <graphics>
51 <offset x="46.0" y="-14.0"/>
52 </graphics>
53 </name>
54 <initialMarking>
55 <value>Default,0</value>
56 <graphics>
57 <offset x="0.0" y="0.0"/>
58 </graphics>
59 </initialMarking>
60 <capacity>
61 <value>0</value>
```

```
 62 </capacity>
 63 </place>
 64 <place id="Light Control ">
 65 <graphics>
 66 <position x="720.0" y="195.0"/>
 67 </graphics>
 68 <name>
 69 <value>Light Control </value>
 70 <graphics>
 71 <offset x="56.0" y="-9.0"/>
 72 </graphics>
 73 </name>
 74 <initialMarking>
 75 <value>Default,0</value>
 76 <graphics>
 77 <offset x="0.0" y="0.0"/>
 78 </graphics>
 79 </initialMarking>
 80 <capacity>
 81 <value>0</value>
 82 </capacity>
 83 </place>
 84 <place id="Room_Lights_Off">
 85 <graphics>
 86 <position x="255.0" y="345.0"/>
 87 </graphics>
 88 <name>
 89 <value>Room_Lights_Off</value>
 90 <graphics>
 91 <offset x="55.0" y="-15.0"/>
 92 </graphics>
 93 </name>
 94 <initialMarking>
 95 <value>Default,0</value>
 96 <graphics>
 97 <offset x="0.0" y="0.0"/>
 98 </graphics>
 99 </initialMarking>
100 <capacity>
101 <value>0</value>
102 </capacity>
103 </place>
104 <place id="Room_Lights_On">
105 <graphics>
106 <position x="405.0" y="345.0"/>
107 </graphics>
108 <name>
109 <value>Room_Lights_On</value>
110 <graphics>
111 <offset x="63.0" y="-12.0"/>
112 </graphics>
113 </name>
114 <initialMarking>
115 <value>Default,0</value>
116 <graphics>
117 <offset x="0.0" y="0.0"/>
118 </graphics>
119 </initialMarking>
120 <capacity>
121 <value>0</value>
122 </capacity>
123 </place>
124 <place id="Room lights ">
125 <graphics>
126 <position x="585.0" y="285.0"/>
127 </graphics>
128 <name>
129 <value>Room lights </value>
130 <graphics>
131 <offset x="40.0" y="-18.0"/>
132 </graphics>
133 </name>
134 <initialMarking>
135 <value>Default,0</value>
136 <graphics>
137 <offset x="0.0" y="0.0"/>
138 </graphics>
139 </initialMarking>
140 <capacity>
141 <value>0</value>
142 </capacity>
143 </place>
144 <transition id="B_Light Control
        System">
145 <graphics>
146 <position x="315.0" y="90.0"/>
147 </graphics>
148 <name>
149 <value>B_Light Control System</
        value>
150 <graphics>
151 <offset x="87.0" y="-21.0"/>
152 </graphics>
153 </name>
```

```
154 <orientation>
155 <value>0</value>
156 </orientation>
157 <rate>
158 <value>1.0</value>
159 </rate>
160 <timed>
161 <value>false</value>
162 </timed>
163 <infiniteServer>
164 <value>false</value>
165 </infiniteServer>
166 <priority>
167 <value>1</value>
168 </priority>
169 </transition>
170 <transition id="R_Light Control
        System">
171 <graphics>
172 <position x="330.0" y="345.0"/>
173 </graphics>
174 <name>
175 <value>R_Light Control System</
        value>
176 <graphics>
177 <offset x="72.0" y="51.0"/>
178 </graphics>
179 </name>
180 <orientation>
181 <value>0</value>
182 </orientation>
183 <rate>
184 <value>1.0</value>
185 </rate>
186 <timed>
187 <value>false</value>
188 </timed>
189 <infiniteServer>
190 <value>false</value>
191 </infiniteServer>
192 <priority>
193 <value>1</value>
194 </priority>
195 </transition>
196 <transition id="T0">
197 <graphics>
198 <position x="645.0" y="150.0"/>
199 </graphics>
200 <name>
201 <value>T0</value>
202 <graphics>
203 <offset x="-5.0" y="35.0"/>
204 </graphics>
205 </name>
206 <orientation>
207 <value>0</value>
208 </orientation>
209 <rate>
210 <value>1.0</value>
211 </rate>
212 <timed>
213 <value>false</value>
214 </timed>
215 <infiniteServer>
216 <value>false</value>
217 </infiniteServer>
218 <priority>
219 <value>1</value>
220 </priority>
221 </transition>
222 <transition id="T1">
223 <graphics>
224 <position x="660.0" y="285.0"/>
225 </graphics>
226 <name>
227 <value>T1</value>
228 <graphics>
229 <offset x="-5.0" y="35.0"/>
230 </graphics>
231 </name>
232 <orientation>
233 <value>0</value>
234 </orientation>
235 <rate>
236 <value>1.0</value>
237 </rate>
238 <timed>
239 <value>false</value>
240 </timed>
241 <infiniteServer>
242 <value>false</value>
243 </infiniteServer>
244 <priority>
245 <value>1</value>
```

```
246 </priority>                          293 <infiniteServer>
247 </transition>                        294 <value>false</value>
248 <transition id="T2">                 295 </infiniteServer>
249 <graphics>                           296 <priority>
250 <position x="495.0" y="285.0"/>      297 <value>1</value>
251 </graphics>                          298 </priority>
252 <name>                               299 </transition>
253 <value>T2</value>                    300 <transition id="T6">
254 <graphics>                           301 <graphics>
255 <offset x="14.0" y="47.0"/>          302 <position x="510.0" y="405.0"/>
256 </graphics>                          303 </graphics>
257 </name>                              304 <name>
258 <orientation>                        305 <value>T6</value>
259 <value>0</value>                     306 <graphics>
260 </orientation>                       307 <offset x="-5.0" y="35.0"/>
261 <rate>                               308 </graphics>
262 <value>1.0</value>                   309 </name>
263 </rate>                              310 <orientation>
264 <timed>                              311 <value>0</value>
265 <value>false</value>                 312 </orientation>
266 </timed>                             313 <rate>
267 <infiniteServer>                     314 <value>1.0</value>
268 <value>false</value>                 315 </rate>
269 </infiniteServer>                    316 <timed>
270 <priority>                           317 <value>false</value>
271 <value>1</value>                     318 </timed>
272 </priority>                          319 <infiniteServer>
273 </transition>                        320 <value>false</value>
274 <transition id="T3">                 321 </infiniteServer>
275 <graphics>                           322 <priority>
276 <position x="480.0" y="150.0"/>      323 <value>1</value>
277 </graphics>                          324 </priority>
278 <name>                               325 </transition>
279 <value>T3</value>                    326 <transition id="T7">
280 <graphics>                           327 <graphics>
281 <offset x="17.0" y="43.0"/>          328 <position x="495.0" y="30.0"/>
282 </graphics>                          329 </graphics>
283 </name>                              330 <name>
284 <orientation>                        331 <value>T7</value>
285 <value>0</value>                     332 <graphics>
286 </orientation>                       333 <offset x="-5.0" y="35.0"/>
287 <rate>                               334 </graphics>
288 <value>1.0</value>                   335 </name>
289 </rate>                              336 <orientation>
290 <timed>                              337 <value>0</value>
291 <value>false</value>                 338 </orientation>
292 </timed>                             339 <rate>
```

```
340 <value>1.0</value>
341 </rate>
342 <timed>
343 <value>false</value>
344 </timed>
345 <infiniteServer>
346 <value>false</value>
347 </infiniteServer>
348 <priority>
349 <value>1</value>
350 </priority>
351 </transition>
352 <arc id="B_Light Control System to
        Bath_Lights_On" source="
        B_Light Control System" target
        ="Bath_Lights_On">
353 <graphics/>
354 <inscription>
355 <value>Default,1</value>
356 <graphics/>
357 </inscription>
358 <tagged>
359 <value>false</value>
360 </tagged>
361 <type value="normal"/>
362 </arc>
363 <arc id="Bath_Lights_Off to
        B_Light Control System" source
        ="Bath_Lights_Off" target="
        B_Light Control System">
364 <graphics/>
365 <inscription>
366 <value>Default,1</value>
367 <graphics/>
368 </inscription>
369 <tagged>
370 <value>false</value>
371 </tagged>
372 <type value="normal"/>
373 </arc>
374 <arc id="Bath_Lights_On to T3"
        source="Bath_Lights_On" target
        ="T3">
375 <graphics/>
376 <inscription>
377 <value>Default,1</value>
378 <graphics/>
379 </inscription>
380 <tagged>
381 <value>false</value>
382 </tagged>
383 <type value="normal"/>
384 </arc>
385 <arc id="Bathroom lights  to T0"
        source="Bathroom lights "
        target="T0">
386 <graphics/>
387 <inscription>
388 <value>Default,1</value>
389 <graphics/>
390 </inscription>
391 <tagged>
392 <value>false</value>
393 </tagged>
394 <type value="normal"/>
395 </arc>
396 <arc id="Light Control  to T6"
        source="Light Control " target
        ="T6">
397 <graphics/>
398 <inscription>
399 <value>Default,1</value>
400 <graphics/>
401 </inscription>
402 <tagged>
403 <value>false</value>
404 </tagged>
405 <type value="normal"/>
406 </arc>
407 <arc id="Light Control  to T7"
        source="Light Control " target
        ="T7">
408 <graphics/>
409 <inscription>
410 <value>Default,1</value>
411 <graphics/>
412 </inscription>
413 <tagged>
414 <value>false</value>
415 </tagged>
416 <type value="normal"/>
417 </arc>
418 <arc id="R_Light Control System to
        Room_Lights_On" source="
```

```
      R_Light Control System" target          457 <tagged>
      ="Room_Lights_On">                       458 <value>false</value>
419 <graphics/>                                459 </tagged>
420 <inscription>                              460 <type value="normal"/>
421 <value>Default,1</value>                   461 </arc>
422 <graphics/>                                462 <arc id="T0 to Light Control "
423 </inscription>                                 source="T0" target="Light
424 <tagged>                                       Control ">
425 <value>false</value>                       463 <graphics/>
426 </tagged>                                  464 <inscription>
427 <type value="normal"/>                     465 <value>Default,1</value>
428 </arc>                                     466 <graphics/>
429 <arc id="Room_Lights_Off to              467 </inscription>
      R_Light Control System" source           468 <tagged>
      ="Room_Lights_Off" target="              469 <value>false</value>
      R_Light Control System">                 470 </tagged>
430 <graphics/>                                471 <type value="normal"/>
431 <inscription>                              472 </arc>
432 <value>Default,1</value>                   473 <arc id="T1 to Light Control "
433 <graphics/>                                    source="T1" target="Light
434 </inscription>                                 Control ">
435 <tagged>                                   474 <graphics/>
436 <value>false</value>                       475 <inscription>
437 </tagged>                                  476 <value>Default,1</value>
438 <type value="normal"/>                     477 <graphics/>
439 </arc>                                     478 </inscription>
440 <arc id="Room_Lights_On to T2"           479 <tagged>
      source="Room_Lights_On" target          480 <value>false</value>
      ="T2">                                    481 </tagged>
441 <graphics/>                                482 <type value="normal"/>
442 <inscription>                              483 </arc>
443 <value>Default,1</value>                   484 <arc id="T2 to Room lights "
444 <graphics/>                                    source="T2" target="Room
445 </inscription>                                 lights ">
446 <tagged>                                   485 <graphics/>
447 <value>false</value>                       486 <inscription>
448 </tagged>                                  487 <value>Default,1</value>
449 <type value="normal"/>                     488 <graphics/>
450 </arc>                                     489 </inscription>
451 <arc id="Room lights  to T1"             490 <tagged>
      source="Room lights " target="           491 <value>false</value>
      T1">                                      492 </tagged>
452 <graphics/>                                493 <type value="normal"/>
453 <inscription>                              494 </arc>
454 <value>Default,1</value>                   495 <arc id="T3 to Bathroom lights "
455 <graphics/>                                    source="T3" target="Bathroom
456 </inscription>                                 lights ">
```

```
496  <graphics/>
497  <inscription>
498  <value>Default,1</value>
499  <graphics/>
500  </inscription>
501  <tagged>
502  <value>false</value>
503  </tagged>
504  <type value="normal"/>
505  </arc>
506  <arc id="T6 to Room_Lights_Off"
         source="T6" target="
         Room_Lights_Off">
507  <graphics/>
508  <inscription>
509  <value>Default,1</value>
510  <graphics/>
511  </inscription>
512  <tagged>
513  <value>false</value>
514  </tagged>
515  <type value="normal"/>
516  </arc>
517  <arc id="T7 to Bath_Lights_Off"
         source="T7" target="
         Bath_Lights_Off">
518  <graphics/>
519  <inscription>
520  <value>Default,1</value>
521  <graphics/>
522  </inscription>
523  <tagged>
524  <value>false</value>
525  </tagged>
526  <type value="normal"/>
527  </arc>
528  </net>
529  </pnml>
```