A Normative Model for Holonic Multi-agent Systems

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***Abstract*—Modeling and design of complex intelligent systems (Intelligent transportation systems, shared health information systems, resource sharing systems, Smart city management systems, etc.) is a very difficult task due to the lack of design processes capable of covering all the characteristics of these types of systems: systems that require both a hierarchical structure which allows to bring together different levels of abstraction within the same system and require the maintenance of regulation and social control of the various entities involved in these systems by using a set of norms. Holonic Multiagent System (HMAS) forms a promising approach to software engineering for the modeling and development of hierarchical complex systems. One of the main challenges currently faced in HMAS research is that of social control. In particular, how can the HMAS be configured and organised given their structure of control and regulation? One of the main solutions is to employ the use of norms. Therefore, norms have been proposed as a mechanism for coordinating and controlling of various entities behaviors involved in the system. In this paper, we propose a new model of norms adapted to the holonic structure of HMAS. To do this, (1) we introduce two new types of norms: internal (private) and external (public) norms; (2) we identify and verify the alignment between these two types of norms. These two types of norms have implications for the control, organization and structure of holons.**

I. Introduction

The management of collaborative work, decentralized processes, distributing information and the interaction of entities and institutions in regulated environments highlight the need for new approaches of design and development of critical and hierarchical complex systems. Holonic multi-agent systems (HMAS) [1][2][3] form an approach for the design of hierarchical complex systems. A complex system is a set constituted of a large number of entities in interaction which prevent the observer from predicting his behavior.

A promising approach in the field of HMAS is the design and development of hierarchical complex systems. In effect, this approach offers new strategies to analyze, design and implement these types of systems. HMASs are considered as societies composed of autonomous and independent entities, called holons [4] - groups of agents, which interact in order to solve a problem or collectively performs a task. An agent is an entity characterized by the fact that it is independent, free to act according to his own choice. It decides its own process if it runs or not a required action. Agents have their own goals and act proactively to achieve it. According to Koestler, holon [4] is a self-similar structure that is stable, coherent and which consists of several holons as substructures. A holon is a component which can be seen both as a component part of a higher level element, and as a whole composed of other holons. Therefore, the notion of holon makes it possible to describe systems of hierarchical nature [5]. A holon has the same properties assigned to agents such as autonomy, social empowerment and proactivity.

The HMAS theory allows recursive modeling of holons and provides a dynamic reorganization mechanism. Depending on the complexity of the tasks the holons can create a sort of hierarchical composition. HMAS offers a promising approach of software engineering making it possible to cohabit different levels of abstraction within the same system. The holonic approach [2] is used to develop applications in complex domains, characterized by a hierarchical structure, facilitate holarchic modeling and encourage modularity and reuse of models. HMASs involve heterogeneous and autonomous holons whose interactions must conform to certain social norms [6] and shared conventions to ensure the social control [6] of the system.

One of the main challenges currently faced in HMAS research is that of social control. However, HMAS does not cover some aspects such as those related to the tasks to be performed by the organization and the rules to be respected to assure the profitable achievement of the organization's objectives. In particular, how can the HMAS be configured and organised given their structure of control and regulation? One of the main solutions is to employ the use of norms for control, regulation, coordination and cooperation of various entities involved in the system. The concept of norms (permissions, obligations and prohibitions)[7] [8] adapts well to the definition of holonomic multi-agent systems. It can be used in HMAS to define behavioral models. Norms specify behaviors that holons should follow in order to achieve the objectives of the system. The use of norms induces a positive impact on the coordination by reducing the uncertainty of the interactions due to the autonomy of holons (decides of its own process if it runs or not a required action). Norms are used to describe the expected behavior of a holon based on the role it plays in an organization. So, norms can increase the level of trust between entities. In order that norms can have an impact on the behavior of a holon, it is necessary that it was capable of taking into account them at the time of the decision of the behavior to be adopted. It is therefore necessary to propose a new internal architecture of holons, allowing to integrate norms in the reasoning of the holons. The main interest of norms is to compromise between the need for autonomy and the need for control. Norms are intended to influence the behavior of a holon and not to dictate its behavior in order to preserve the principle of autonomy of the holon.

Several proposals on normative models[10] [11] for multi-agent systems (MAS) [9] have been made in order to design agent societies in environments governed by norms. However, they are not adapted to support holonic systems, i.e. those who allow to model complex organizations involving several levels simultaneously. In consequence of the hierarchical structure of the system at the same time as the heterogeneity and autonomy of the holons participants, this type of society needs the adaptation and modification of the normative context.

In this paper, we propose a new model of norms adapted to the holonic structure of HMAS. To do this, we (1) introduce two new types of norms: internal (private) and external (public) norms; (2) identify and verify the alignment between these two types of norms. These two types of norms have implications for the control, organization and structure of holons. A technical point of view usually puts the importance of applying these two types of norms for engineering processes, usually as a form of regulation and control within a holon. In this way, these norms are considered another way (in the same vein as the contracts, protocols, etc.) to accomplish a specific task.

The rest of this paper is organized as follows: Section II presents a motivating example; Section III makes an overview of works on normative model and section IV will detail our model of norms adapted to HMAS. The last section concludes our paper and gives same future works.

II. Motivating example

In this section, we present a motivating example, the design of Smart City Management System, which will be used throughout this paper to illustrate our normative model for HMAS.

Smart City is an innovative city that uses the Information and Communication Technology (ICT). The ICT covers all areas of smart city such as government facilities, buildings, traffic, electricity, health, water and transport. Smart city must include: intelligent energy, smart buildings, intelligent transportation, intelligent management of the water and the waste, smart security and safety, intelligent health care and intelligent education.

New Information and Communication Technologies (intelligent sensors and meters, digital media, information devices, etc.) will be at the heart of the smart city. Development of ICTs will allow better urban management by obtaining and analyzing of information key (operation of renewable electricity production facilities, real-time state of public distribution networks, road traffic monitoring, measuring levels of pollution, etc.) through an urban operating system and a new knowledge management infrastructure. ICTs allow to coordinate and to automate the operation of a city's electrical equipment in order to save energy, to improve comfort and security in the city.

Definitions of smart city can be distinguished in two categories: (i) that focused on the needs of the occupants; and (ii) that focused on technology in service of the smart city. Smart city integrates the best existing concepts (materials, systems and technologies) to meet the requirements of managers and users on a local and global scale. Smart city should maximize the efficiency of its occupants and enable effective management of resources with minimal costs. Smart City has a lot of features: (i) improved comfort in buildings (heating, air conditioning, ventilation and electric lighting); (ii) help to the surveillance and the security in the building; (iii) managing power consumption and helping to reduce energy consumption; (iv) improvement of the energy efficiency of buildings.

Smart city is composed of multiple heterogeneous and complex entities interacting with each other. In order to meet the needs of all these entities, smart city must anchor his development in respect of a set of social norms and shared agreements. The smart city management system is a hierarchical system and requires social control. The normative model for HMAS proposed in this paper allows the modeling of this type of system, which requires a hierarchical structure and social control.

From a holonic point of view, we can decompose the smart city into several smart neighborhoods. The holon Smart city (H1) is composed of several Smart Neighborhoods. The holon Smart Neighborhood (H2), level n, is composed of three holons as substructure, in level n-1, namely Smart Road Network (H3), Green Space Management System (H4) and Smart Buildings (H5). Each of these last three holons (H3, H4 and H5), level n-1, is composed of several holons as sub-structure in level n-2. For example, the holon H5 (Smart Buildings), level n-1, itself is composed of several holons, of the n-2 level, namely Smart Office (H14), Police City Station (H15), Smart Hospital H16) and Smart Apartment Buildings (H17). The holon H17 (Smart Apartment Buildings), level n-

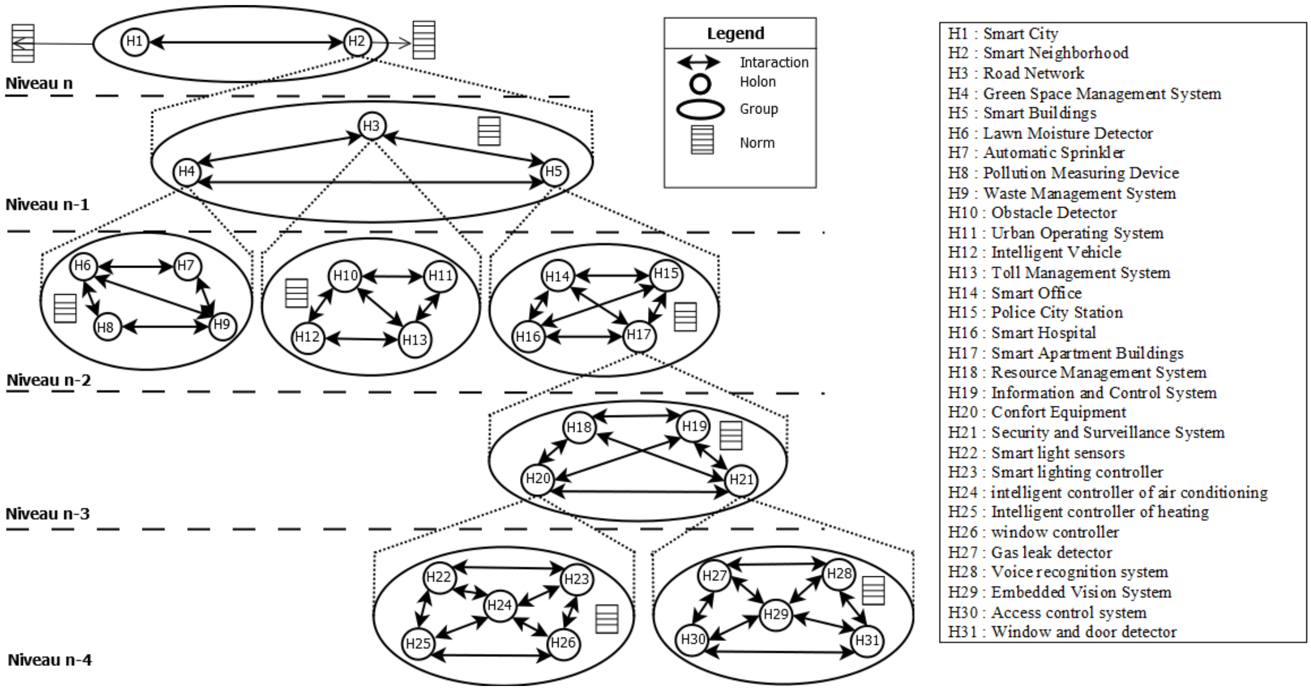

Fig. 1. Normative holonic structure of smart city

2, itself is composed of several holons as substructure, level n-3, namely the Holon Resource Management System (H18), Information and Control System H19), Comfort Equipment (H20) and Security and Surveillance System (H21). At the lowest level (level n-4) are intelligent sensors, smart meters, digital media and information devices, where n is the hierarchical level number of our system - Smart City Management System, n = 5 levels here. This holarchy of the smart city is described in Fig.1.

From a normative point of view, we define a set of norms that govern behavior patterns for a smart city. Smart city is modeled as a set of holonic organizations that define several roles. Norms are integrated into the actions and guide the execution of the actions of the holons to achieve the appropriate objectives. Smart city control requires a set of norms that specify what actions are necessary in certain situations. An informal specification of some norms in the smart city management system is reported below:

Norm 1: Smart City is obliged to improve surveillance, safety of users.

Norm 2: Smart City is obliged to reduce energy consumption.

Norm 3: Smart City is obliged to improve comfort of users.

Norm 4: Smart City is obliged to respect the environment (green space) by reducing the production of waste.

Norm 5: If the room temperature is higher than expected temperature and outside temperature is lower than the temperature of the room so the controller of the window is obliged to open the window.

Norm 6: If room temperature is higher than expected temperature and the outside temperature is higher than the temperature of the room so the controller of the window is obliged to close the window and the controller of the air conditioner is obliged to open the air conditioner.

Norm 7: when the gas leak detector detects leaks in the air ducts, the window controller is obliged to open the window.

Norm 8: For security reasons, the window controller is forbidden to open the window between 22:00 and 05:00.

III. Related Work

Much work has been done on the normative models to design complex and dynamic agent organizations. For example, the work described in [12] provides an overview of the concepts that are used to model the social norms that govern the behaviour of autonomous agents. Most of these concepts can be modeled using deontic notions. This work divides the norms over three levels: the private level, the contract level and the convention level. Dividing the concepts over three levels makes it possible to structure the different social interactions of an agent.

Other normative model was proposed [13] for formalizing agent commitments. This model highlights the interplay between commitments and the structure of multiagent systems. Also, the work described in [14] proposes a social law approach which is aimed at representing norms which are imposed to the society members by an authority.

The models mentioned above are the first work on normative models for agent organizations. They provides an overview of the normative concepts which govern the behaviour of autonomous agents. This models present some limits when supporting normative MAS. They only offer support on covering one norm level. Thus, these models do not completely support the analysis and the design of normative organizational

MAS, but only give support to the regulative dimension of norms.

Recently, new proposals on normative models have been proposed in order to implement complex agent organizations. For example: a normative organizational model has been proposed in [15] , called Moise+. This model specifies a set of constraints for agents along three dimensions: a structural specification, functional specification and deontic specification. Moise+ facilitates the modeling of a system at different levels of abstraction since there is the concept of group and subgroup. The Moise+ model is an attempt to unify these two families, so we find it a structural specification and functional specification (goals to reach). To explain how the agents work together to contribute to common goals, these two specifications are connected by deontic specification.

Also, new proposals on normative models were made to design methodologies for the analysis and design of normative open MAS. The work described in [16] proposes a methodology, called ROMAS, for the analysis and the design of normative open MAS. This methodology is focused on the analysis and design processes for developing open organizational multi-agent systems where agents interact by means of services, and where social and contractual relationships are formalized using norms and contracts. In ROMAS methodology, agents, roles and organizations are defined by a social structure based on a service-oriented open MAS architecture. The organizations are designed as an effective mechanism for imposing restrictions on their structural relationships and normative restrictions on their behavior. This methodology presents certain limits, it only offers support to one norm level. It does not consider the different levels of abstraction.

Other normative models have been proposed in [17] and [18]. These models allow the definition of norm-governed Electronic Institutions. These works aimat adding exibility and generality to electronic institutions by extending their deontic components through richer types of norms that can still be enforced on-line.

The above mentioned models present some limits when supporting hierarchical normative systems.However, they are not adapted to support holonic systems, i.e. those who allow to model complex organizations involving several levels simultaneously. A hierarchical normative system is a legal system where norms are arranged in a hierarchy of norms. It is composed of many authorities which are linked by hierarchical relations. Moreover, a normative system has a dynamic character: norms are added to the system one after the other and this operation is performed by different authorities at different levels of the hierarchy.

In the field of normative holonic multi-agent systems, only one work was proposed, that of Massimo Cossentino et al in [19]. This work presents an idea to integrate Moise+ models with ASPECS [20] methodology, to provide abstractions and manage the normative aspect of an organization. They made an extension of ASPECS to include the elements of Moise+ models. This extension supports the organizational and normative principles. This new model allows to define models not only from the point of view of the holonic agent, but also the point of view of the normative organization. ASPECS manages abstractions, as holons, for the modelling and organizational structures as holarchy [5]. Moise+ handle organizational aspects of the MASs by modelling three different perspectives: the functional, the structural and the normative. The resulting model combines the strength of ASPECS and Moise+ to create a support for the development of structured organizations of MASs as holarchies [5], which are also by norms. At the end, they instantiated this new metamodel in a logistic model of specific business, which also integrates the virtual enterprise paradigm. The work of Massimo Cossentino et al mentioned above present certain limits. This work provides an overview to integrate Moise+ models with ASPECS methodology. It does not consider the influence of norms on the holon architecture and the hierarchical structure of the system. Also, it does not consider the coherence of norms in hierarchical normative systems.

In this paper, we proposed a new model of norms adapted to the holonic structure of HMAS. In this model, we have proposed two new types of norms: internal (private) and external (public) norms. Then, we identify and verify the alignment between these two types of norms.

IV. A Model of norms adapted to HMAS

In this section we present a new model of norms aimed at maintaining social control, cooperation and coordination between holons activities in critical hierarchical systems. This model takes its inspiration from human legal systems [21] [22].

As it is well known, there are different types of organizational schemes, such as hierarchies, holarchies, teams,etc. Each organizational scheme is usually defined through roles adopted by an holon, relationships, rules and norms that define holon behavior and organizational structure.

A holon is, usually, defined as an auto-similar structure composed of holons as substructures. For this reason, it can be seen from different points of view, whether as an autonomous atomic entity or as a holons organization.

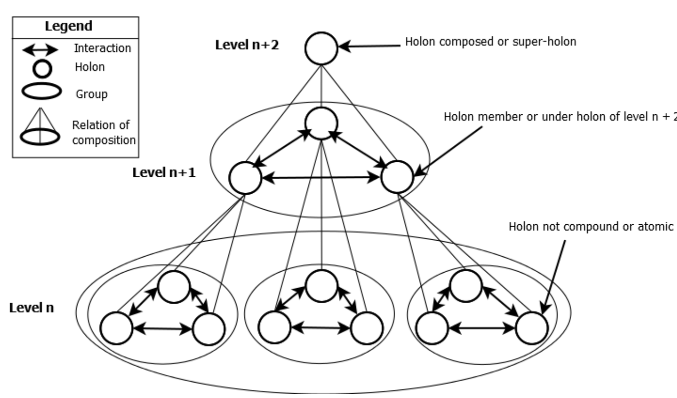

Fig. 2. The concept holon

Figure 2 summarizes the definition of holon such that it is considered in the HMAS. Holons of level n are grouped

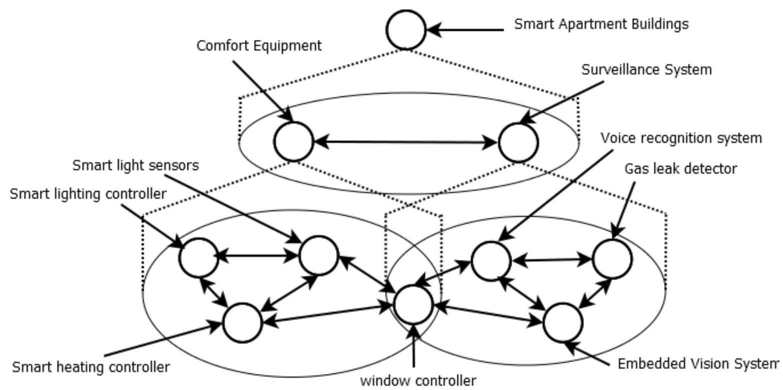

Fig. 3. Example of holarchical structure of Smart Apartment Buildings management system

in organization which at level n + 1 can be considered as individual entities. Conversely holons considered as individual entities of level n + 1 can be considered as organizations at level n. This hierarchical composition process can be repeated on an arbitrary number of levels.

If we consider Smart Apartment Buildings from a holonic point of view, we can then break it down into Comfort Equipment and Surveillance System. The holarchy structure of Smart Apartment Buildings is described in Figure 3.

A holon is a whole-part composed of other holon and at the same time, a component of a higher-level holon. A holon therefore acts as an autonomous entity, although cooperating to form hierarchies of self-organization of subsystems in order to achieve the objectives of the holarchy. In addition, holons can simultaneously belong to different superholons and can be regulated by social norms. These norms not only make it possible to define a system as a holon with its own individuality, but also to determine its structural configuration, functional models and behavioral norms. Representation of norms involves deontic expressions such as obligation, permission, prohibition, law, power, duty, etc. The formalization of these notions gave birth to the deontic logic. [23] [24]. The modal logic is built as an extension of the classic propositional logic to which we add one or several modal operators. In the case of deontic logic, the modal operators that are introduced are: (O) for OBLIGATION, (P) for PERMISSION and (F) for FORBIDDEN. The norms governing the behavior of these holons are also described, using the the following template:

$< norm >$::= $< entity >$ 'IS' $< deontic\_concept >$ 'TO'
$< norm\_description >$
$< entity >$::= 'Holon' | 'Agent'
$< deontic\_concept >$::= 'OBLIGED' | 'FORBIDDEN' | 'PERMISSION'
$< norm\_description >$::= $\{< action >< sanction >\}$
| $\{< action >< temporal\_situation >< sanction >\}$
| $\{< action >$ 'IF'$< condition >< sanction >\}$
|
$\{< action >< temporal\_situation >$'IF'$< condition >< sanction >\}$
$< action >$::=$< entity >$ 'EXECUTE' $< exec >$
$< temporal\_situation >$::= BEFORE $< situation >$
| AFTER $< situation >$
| BETWEEN $(< situation >, < situation >)$
$< exec >$ ::= $< class >$. $< method >$ $(< parameters >)$
$< condition >$::=$< variant >< operator >< variant >$
| $< normative\_result >$ $(< norm >)$
$< normative\_result >$::= FAILED | SATISFIED
$> operator >$::= > | < | >= | <= | = | $\subseteq$
$< variant >$::= $< atomic >$ | $< formula >$ | value
$< atomic >$::= variable | identifier.attribute
$< formula >$::= identifier(<args>)
$< sanction$::= $< punishments >< rewards >$
| $< punishments >$
| $< rewards >$
$< punishment >$::=$< authority >$ 'PUNISHES' $< action >$
| $< authority >$ 'PUNISHES' $< expression >$
$< reward >$::=$< promoter >$ 'REWARDS' $< action >$
| $< promoter >$ 'REWARDS' $< expression >$
$< authority >$::= $< entity >$
$< promoter >$::= $< entity >$

For example, Specifying Norm 6, If room temperature is higher than expected temperature and the outside temperature is higher than the temperature of the room so the controller of the window is obliged to close the window and the controller of the air-conditioner is obliged to open the air-conditioner; the template for this norm would be:

Specifying Norm 5:
$((< the\_controller\_of\_the\_window >$ 'IS'
$< OBLIGED >$ 'TO' $< close\_the\_window >)$ 'AND'
$(< the\_controller\_of\_the\_air-conditioner >$ 'IS'
$< OBLIGED >$ 'TO' $< open\_the\_air-conditioner >))$
'IF' $((< room\_temperature > expected\_temperature >)$
'AND'
$(< outside\_temperature > room\_temperature >))$

In this paper, we propose a model of norms adapted to the holarchical structure of the HMAS. To do this, we propose two new types of norms: internal (private) and external (public) norms, necessary for the design of the holons internal architecture and the definition of its structural configuration. These two norms act as behavioural constraints which regulate and structure the social order in composed holon and promote cooperation and coordination between members of this holon. They are a form of regulation and control within holon.

A. Internal and External Norms

In this model, we distinguish between two new types of norms that take into account the static and dynamic aspects of a holon, named internal (private) and external (public) norms. Internal norms relating to sub-holons belonging to the same super-holon and the external norms concerning to sub-holons belonging to different super-holons.

Definition 1 (Internal norm): Internal norms govern the internal functioning of a composed holon. A composed holon is seen as a set of holons members. These norms address the protection of private data, the management of heterogeneous databases, the scaling-up, the confidence of the data transmitted and received. Its define the structural aspect of this composed holon to achieve its objectives.

Internal norms are used to guide and control the performance of actions in a specific context. An internal norm can explicitly establish a forbidden, obligation or permission on the behaviour of a holon in a given context.

Definition 2 (External norm): External norms govern the interaction of a holon with its peers. They represent the commitments between several entities to formalize exchange services or products.

External norms allow autonomous and heterogeneous holons to interact, publish their functionality and capabilities, and engage in peer-to-peer interactions with other holons. The interaction must be well defined so that message interpretation, authorized actions and expected responses are not ambiguous. These norms allow to define inter-holons agreements. Before engaging in an interaction, holons must agree on the procedures of their common process.

The normative holon is considered as a set of internal norms which govern its internal behavior and a set of external norms which formalize its relationship with its peers.

Some structures defining the distribution of powers within a super-holon. The holonic organization was originally designed to describe the management and structure of a super-holon in terms of distribution of authority and power.

To represent a holonic group, five roles, called holonic roles, have been identified:(i) Head: represents a privileged status to which members may confer some degree of authority and certain special rights. It takes part in the decision-making process and it ensures part of the super-holon administration burden. This load depends on the configuration chosen and may vary during the life of the super-holon; (ii) Representative: it is part of the visible interface of the super-holon. It plays the role of interface between the inside and the outside of the super-holon. It ensures the redistribution and the eventual translation of information from outside. It represents the other members outside the super-holon. Several Representatives can be in charge of representing the other members; (iii) Part: identifies the members of a single super-holon. They are normally in charge of the execution of the tasks assigned to them by the Heads. They may take part in the decision-making process. This participation in the decision-making process depends on the chosen government structure for the super-holon; (iv) MultiPart: extending the Part role, it identifies members shared between several super-holons.The fact that a member can be shared between several super holons may generate conflicts of interest or authority. If during the life of the super-holon, one of its members Part joins another super-holon, it must change the role to become MultiPart; and (v) Stand-Alone: this role represents the status attributed to the non-members holons. All non-member holons are external to the super-holon, and are perceived by the members through the Stand-Alone status. This role was added to manage the recruitment of new members within a super-holon.

The first four holonic roles describe the status of a member within a super-holon and participate in the definition of holonic organization. Each of these roles can be played by one or more members, knowing that any super-holon must have at least one Representative and one Head. Each Member of a super-holon must play at least one role in this group, aand any holon that joins the super-holon after its creation, will also play a role in this group. The holonic organization generally defines the distribution of powers within a super-holon, and specifies how decisions are made. It is also possible to override this global behavior by creating a specific production organization to specify how decisions will be made for specific objectives or tasks.

Figure 4 details the example of a holarchy of Smart Apartment Buildings illustrating the holonic ogranization and administration aspect within a super-holon. The Smart Apartment Buildings is composed of a Comfort Equipment and a Surveillance System. It requires a set of norms that specify behaviors that holons should follow in order to achieve the objectives of the system.

Specifying Norm 4.1: $< Comfort\_Equipment >$ 'IS' $< OBLIGED >$ 'TO' ($< consume(energie) >$) < 3 KWH

Specifying Norm 4.2: $< the\_smart\_heating\_controller >$ 'IS' $< OBLIGED >$ 'TO' ($< consume(energie) >$) < 1 KWH

Specifying Norm 4.3: $< the\_smart\_lighting\_controller >$ 'IS' $< OBLIGED >$ 'TO' ($< consume(energie) >$) < 1 KWH

Specifying Norm 4.4: $< Surveillance\_System >$ 'IS' $< OBLIGED >$ 'TO' ($< response\_time >$) < 5 s

Specifying Norm 4.5: $< Gas\_leak\_detector >$ 'IS' $< OBLIGED >$ 'TO' ($< response\_time >$) < 4 s

Specifying Norm 4.6: $< Voice\_recognition\_system >$ 'IS' $< OBLIGED >$ 'TO' ($< response\_time >$) < 2 s.

Specifying Norm 4.7: $< Surveillance\_System >$ 'IS' $< OBLIGED >$ 'TO' ($< security >$) < 3

Specifying Norm 4.8: $< Gas\_leak\_detector >$ 'IS' $< OBLIGED >$ 'TO' ($< security >$) < 3

Specifying Norm 4.9: $< window\_controler >$ 'IS' $< OBLIGED >$ 'TO' ($< security >$) < 2.

Norms 4.1 and 4.4 are two external norms respectively of two super-holons,Comfort Equipment and a Surveillance System. Norms 4.2 and 4.3 are two internal norms of the super-holon Comfort Equipment. Also, norms 4.5 and 4.6 are two internal norms of the super-holon Surveillance System.

After describing the structure of holon, defining its internal state with internal norms, and defining its interactions with other holons using external norms, we can define the normative holon.

Definition 3 (Normative Holon): A Normative Holon is defined as a tuple $NH_n = \langle R_n, H_{n-1}, G, \varphi, N_n \rangle$ where:

- NH_n: is a normative holon of level n
- R_n: is a set of roles played by NH_n

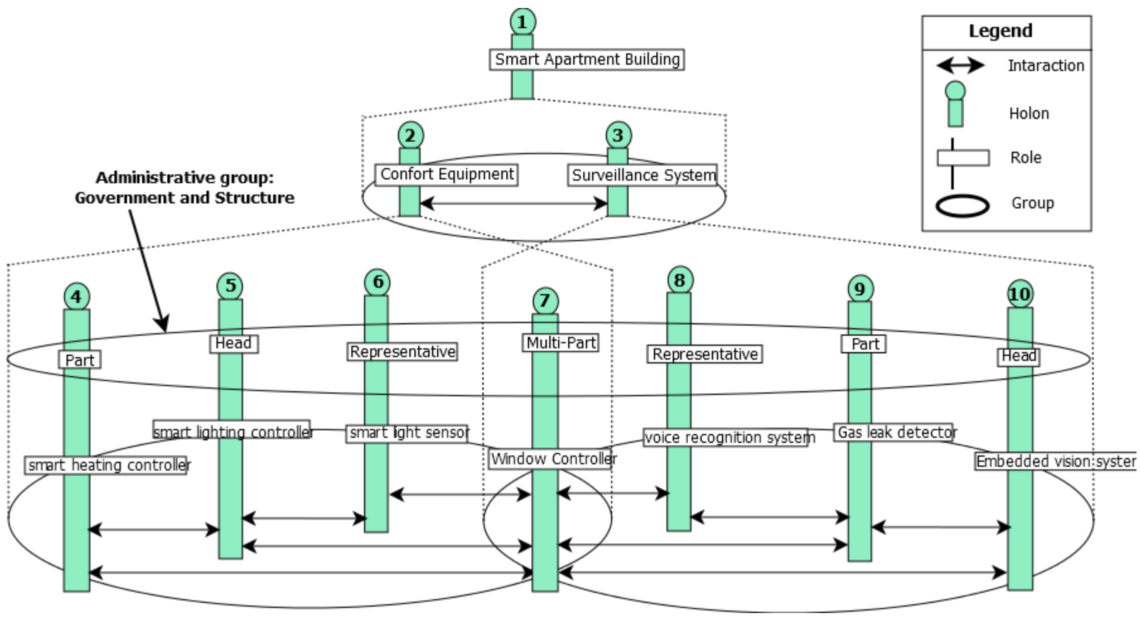

Fig. 4. Government and structure of Smart Apartment Buildings management system

- H_{n-1}: is the set of sub-holons members of the super-holon NH_n
- G: is the set of groups that participates in the operation of the super-holonNH_n
- φ:•] NH_{n-1} $\longrightarrow$roles(G) : A function that matches each sub-holon member to the set of roles it plays in the groups G defined within NH_n
- N_n: = { n_1, n_2, ..., n_m } is a finite set of norms. Each norm n_i has the form n_i=$\langle$ NR, OP, P $\rangle$ where: NR is the role to which the norm is addressed (the target of the norm); OP $\in$ { O, F, P } is the deontic modality of the norm, determing if the norm is an Obligation(O), Forbidden(F) or Permission(P); and P is a property (the object of the norm)

For example, the norm that obliges the economy of energy in the sub-holons members Comfort Equipment of the super-holon Smart Apartment Buildings is represented as follows:
$\langle$ O, economy(energy) < 10 kw, Comfort Equipment$\rangle$

This model of norms should also provide mechanisms for verifying the consistency of norms and the alignment between internal and external norms in a super-holon.

B. Alignment between internal and external norms

The alignment is realized around the coherence between the internal and external dimensions of a super-holon. The alignment is realized around the coherence between the internal and external dimensions of a super-holon. The alignment process involves exploiting the relationships between internal and external norms to improve the coherence of a super-holon. Alignment is an essential property of resolving conflicts between the internal and external regulation of a composed holon. There is an internal alignment of a holon member with its own objectives, and another level of alignment with other members of a super-holon to achieve the overall goal of the system. The alignment between internal and external norms is described in Fig.5.

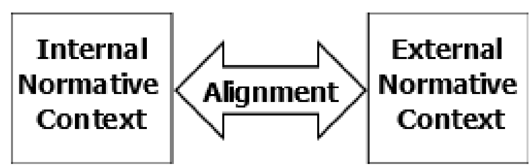

Fig. 5. Alignment between internal and external norms in a super-holon

The normative holon is considered as a set of internal norms which govern its behaviors, and a set of external norms which formalize its relationships with its peers. The normative context of each sub-holons members of the super-holon is specified by the set of norms which directly affect the behavior of this entity. The normative context of a super-holon is the set of norms which affect only sub-holons members which are a part of this super-holon.

In order to establish the alignment between these two types of norms (internal and external), a deduction system is introduced which makes it possible to deduce the external norms of a super-holon from its internal norms. This deduction is represented as follows:

$$\mathbf{NI_1, NI_2, ..., NI_n \vdash NE}$$

Where NI_1, ..., NI_n designate Internal norms, and NE the external norm generated from internal norms. The sign $\vdash$ indicates the deduction.

For example, The external norm 4.1 can be deduced from internal norms 4.2 and 4.3.

$$\mathbf{4.2, 4.3 \vdash 4.1}$$

Also, external norm 4.4 can be deduced from internal norms 4.5 and 4.6.

$$\mathbf{4.5,\ 4.6} \vdash \mathbf{4.4}$$

In this way we can guarantee the alignment between the internal and external norms.

V. Conclusions and Future Work

In this paper, we have proposed a new model of norms adapted to HMAS. In this model, we have proposed two new types of norms: internal (private) and external (public) norms. Internal norms describe the management and internal structure of a super-holon in terms of power and authority distributions. External norms govern the interaction of a holon with its peers. They represent the commitments between several entities to formalize exchange services or products. These two new of norms act as behavioural constraints which regulate and structure the social order in composed holon and promote cooperation and coordination between members of this holon.

Our model of norms allows verification of alignment between internal and external norms in a holon. Our next work focuses on the verification of the consistency of the inter-holons norms,i.e., the external norms of two super-holons. To avoid interoperability problems, one of solutions is to use communication norms. These norms should clearly specify how to integrate external entities in a super-holon and the way in which they must communicate and interact with each other. We will present in a future paper an extension of our model of norms by adding a mechanism to ensure communication between two super-holons and enforcement of the sanction in the case of violation of norms.

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