

An Analysis of Norm Processes in Normative Multi-agent Systems

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Abstract—The multi-agent system paradigm has proved to be very promising for solving complex problems because agents are able to behave autonomously and cooperate to achieve common goals without the need of a central authority. However, sometimes the need to introduce a control on a society of agents is observed in order to make them operate under a set of rules, as in a human society. Several studies have addressed the study of normative concepts in multi-agent systems, however there is a lack of an adequate systematization of life cycle stages and techniques to guide each one of them. This article analyzes the state of the art of norm processes in normative multi-agent systems.

Keywords—Normative Multi-agent Systems, Norms, Norm Processes, Norm Life cycles.

I. INTRODUCTION

Multi-Agent Systems (MAS) allow to approach complex problems through autonomous computational entities (software agents) capable of working in dynamic environments. In MAS systems, each agent handles a subproblem of the main problem and shares information with its peers in order to achieve the overall system goal, working coordinately, cooperatively or competitively. Agents do not work in isolation, because they are part of a society, may share the same goals [1], or have conflicting ones. Therefore, it is necessary to introduce norms and normative concepts in MAS in order to accurately describe the behavior of the system [2], prevent conflicts, ensure coordination [3], cooperation [4] and promote harmonious coexistence among agents.

Smart agents are entities aware of their surrounding social environment which directs how they perform their tasks. They need to interact with other agents in order to perform social acts in a controlled society and thus are subject to norms in a normative system context. The understanding of norms life-cycle and their update to an IoT / IoA context is crucial to those modern, complex, diverse and highly interactive multi-agent environments.

A process is a model that specifies a life cycle describing the stages considered through which norms go through from its conception to its establishment in a society. It's also composed of a methodology that incorporates techniques to be applied in each stage according to the approach adopted [5].

II. SYSTEMS, AGENTS E NORMS

Although many researchers consider Normative Multi-Agent Systems (NMAS) as an intersection between MAS and

Normative Systems (NS), we can broadly regard them as the union of components that bring in them some characteristics that, when added to an existing component augments its meaning and adds value to the whole.

Broadly, we can see a system as a set of connected parts forming a complex whole. Complex systems are formed by single units that are interconnected, so that the behavior of each unit influences the behavior of others and dynamically feeds back on the system itself.

Agents are entities that have the ability to emulate a real world element, they have a predefined behavior that will be adjusted at runtime. According to [6] apud [7] some properties of agents are: autonomy, social ability, reactivity and proactivity. Thus, agents are autonomous entities because they operate without direct intervention from humans and they have control over their actions and internal state. They have the ability to interact with other agents (and possibly humans), what ensures the development of social skills when compared to other computational entities. Regarding reactivity, agents perceive their environment and respond in a timely manner to changes that occur, they may even display proactive behavior for decision making.

Norms represent desired behaviors of a natural or artificial community and are generally understood as directions on actions expected to be held [8] [9]. Norms serve as guidelines for actions that apply to specific situations (e.g. acquisition and extinction of certain behavior in a social environment) and are fundamental to the understanding of social control and its variation among populations [10].

In MAS's context, norms typically refer to restrictions on behavior, and obligations of agents, and act as regulator mechanisms in decentralized systems [11].

In Tuomela apud [12], norms are classified into four different categories: rule norms, social norms, moral norms and prudential norms. **Rule norms** are norms imposed by authorities of a social group based on agreements among its members. **Social norms** are norms for large groups organized into societies, such as those applicable to a society of students. **Moral norms** refer to internal beliefs of each individual and are related to their habits and beliefs of right and wrong, of good and evil, honesty, among others. **Prudential norms** are based on rationality norms. Prudential norms, according to [13], are rules of prevention and precaution, are characterized by the introduction of prudential criteria in the management of institutions.

III. NORMATIVE MULTI-AGENT SYSTEMS

As defined in [2] apud [11], a given system is considered normative when legal norms and normative concepts are required to accurately describe the behavior of this system. We understand normative concepts as those sub-elements present in this type of system, such as the role each individual plays within the system, the norms themselves, and the definition of obligations, permissions and prohibitions related to the system are examples of normative concepts.

In our society we can identify three types of normative systems in action: **law**, **religion** and **moral**. In the past, the separation among these three normative systems was not very clear. For instance, in the Middle Ages, the Church was considered the legislative system of greatest influence, and had the power to sentence to death those who were against its laws and regulations. Another example is the Ten Commandments that clearly mixed precepts that are now said to be moral (“*Honor your father and your mother*”, “*You shall not covet*”), religious (“*You shall have no other gods before Me*”, “*You shall not take the name of the LORD your God in vain*”) and lawful (“*You shall not steal*”, “*You shall not bear false witness against your neighbor*”).

According to [14], the legal system is a normative system because the structure of expectations regarding values, programs, functions and people, is comprised by norms. Other examples are social etiquette, transit system and sports, because they all have a set of norms and normative concepts that regulate the system.

Norms can be applied in various fields in order to regulate the cooperation of agents, such as traffic lights coordination, intrusion detection techniques in wireless systems [15], real-time vehicular control [16] and E-health systems [17].

NMAS combine features of Multi-Agent Systems and Social Norms. Thus, those systems have the ability to incorporate individual and social factors in order to achieve a high level of accuracy with respect to social phenomena modeling such as cooperation, coordination, group decision-making, among other systems composed of artificial or human agents [18].

Analogous to the interaction in human societies, the existence of norms in MAS is necessary to introduce some kind of social control of agents in order to ensure that the system operates efficiently and, at the same time, allows the agents to maintain their autonomy [11] [18]. Adherence to norms enables agents to behave properly despite the lack of a central control [19].

Norms introduce restrictions on the behavior of agents, by describing obligations, prohibitions and permissions. They also specify responsibilities, benefits and penalties for non-compliance with the norms by its members. Thus, norms dictate as individuals in a society should behave and what to expect from others, enabling agents to plan their actions appropriately [20].

A. Roles associated to Norms

According to [21], some roles associated with the life cycle of the norms can be identified, ranging from the creation of an agent that exhibits, besides the ability, the authority to create

norms to agents that are impacted directly by the compliance or violation of the norms. Such roles are not mutually exclusive and an agent can assume more than one role at the same time. There are four roles listed in that work:

- 1) **Legislator** – The legislator agent is an agent that has the ability and authority to create, modify, or even abolish a norm, or a set of them, in a society;
- 2) **Defender** –The defender agent is an agent responsible for applying the punishment (negative sanctions) when a certain norm is violated, or give the prize (positive sanctions) in case this norm has been followed.
- 3) **Addressee** –The addressee is an agent that has the responsibility to follow the norm, or is the agent to which certain norms are applied. A norm may be applicable to a specific agent, to a group, or to the whole society.
- 4) **Beneficiaries** – Beneficiaries are agents whose goals benefit from norms being met, i.e. by complying with the norm, a given agent within a society can benefit from the results of their fulfillment, and then plan its actions to achieve its goals, whether individual or systemwide.

Similarly, [22] identifies three groups of agents to which a norm could be directly associated: Addressees, which describe who is addressed by normative instruction; that is, to whom the normative statements apply; a group of Actors that describe who should achieve the goal or action claim that the norm refers to; and a group of Responsibilities that describe who cares for the norm to be maintained, and, additionally, can apply sanctions if the norm is violated.

IV. NORM PROCESSES

A. Norms in human societies

In this paper we highlight the work of [23] to propose a three stage model to understand the life cycle of norms (Figure 1). The first stage, norm emergence is the creation of a norm by a leader or an entrepreneur who will then persuade other actors to follow that norm. The second stage, norm cascade, is the spreading of the norm through imitation mechanisms. These two initial stages are separated by a threshold beyond which a critical mass¹ of actors adopts the norm. And finally, the third stage is norm internalization, where it is accepted without questioning or objection by the society.

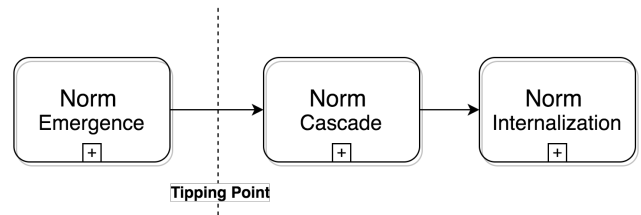


Figure 1. Norm Life cycle proposed by Finnemore & Sikkink (Adapted from [23])

¹The term Critical Mass is often used to describe a minimal amount of individuals needed in a social system so that it can become self-sustaining and permits growth.

As an example, the authors cite the case of women’s right to vote, of slavery and of the idea that doctors and health professionals have immunity during a war. These issues are now indisputable in most societies, but it was not always so.

On the women’s vote in the end of the 19th century various organizations internal to countries defended this right, but only in 1904 with the creation of *International Women’s Suffrage Association* (IWSA), which launched an international campaign, this idea became more widespread and gradually accepted by States. History shows that between 1890 and 1930 few countries had actually allowed female vote, but from 1930 due to international influences, several countries had to ensure that right. This shows that sometimes, in order to a norm to be accepted in a group, an external pressure is necessary to persuade the leaders of that group to follow that norm.

B. Norm Identification in artificial societies

More recently, [24], based on the work of [23], proposed an evolution of the life cycle of norms by adopting a different taxonomy of stages and subdivided them into phases ranging from creation to establishment and disappearance within a given social group (Figure 2). Savarimuthu highlights three stages in this cycle: formation stage, that describes how actors create norms in society and how they identify those that were previously created; propagation stage, that refers to the mechanisms of dissemination of norms and how they are enforced in society (*enforcement*); and emergence stage, characterized by the extent that the norm reached in that milieu. Additionally, from these three stages, this author identifies five phases in the life cycle of norms: creation, identification, spreading, enforcement and emergence.

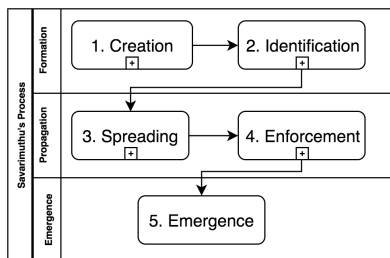


Figure 2. Norm Life cycle proposed by Savarimuthu (adapted from [24])

In the creation phase, a norm can be proposed by a leader agent. Thus, a new agent entering that society can identify the norm by observing its compliance by other members of society. In the spreading phase, once an agent has identified a norm in a society, it can contribute to its spreading by acting as a multiplier of that behavior. A sufficiently widespread norm in a society will have mechanisms to ensure its compliance, usually through positive sanctions (rewards) or negative ones (punishment). Finally, a norm is considered assimilated (emerged) when it is recognized and followed by a considerable number of agents in that society.

As an example, Savarimuthu, to illustrate how a software agent identifies obligation norms in a society, simulates a restaurant scenario². In this scenario, a new agent entering a restaurant may not be aware of the associated protocol to order

and pay for food. This protocol may be first order and pay for food, before consuming, while another may be to order, eat and pay only at the end. Moreover, the tip in some countries, it is expected that the customer give the tip only after paying the bill (the U.S.), a tip is not expected (New Zealand), whereas in Brazil, the tip is already included in the bill, similar to a tax. This, of course, varies according to culture, and non-compliance with this norm may result in sanctions. Thus, a new agent that comes to the restaurant learns about the tipping protocol by observing interactions among other agents, and from the observed sanctions it can then infer the desired behavior in that situation.

C. Life cycle of evolutionary norms

Hollander proposes a model-driven process for the life-cycle of norms, identified by following normative processes: creation, transmission, recognition, compliance (*enforcement*), acceptance, modification, internalization, emergence, forgetfulness and evolution. From these, he identified three super-processes: compliance, internalization and emergence, and additionally, evolution is considered an end-to-end process. This author emphasizes the evolutionary nature of norms and introduces the notion of norm oblivion.

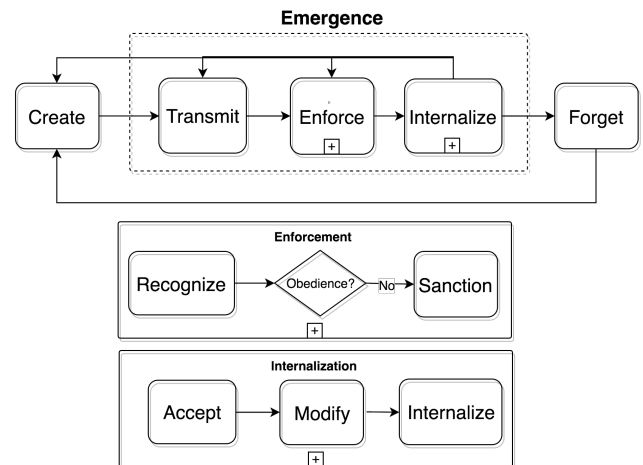


Figure 3. Evolutionary life cycle (adapted from [11])

In this proposed life cycle, ideas that are potential norms are created as part of an evolutionary process (Figure 3). They are spread by passive or active transmission. And as agents are exposed to a new norm, enforcement mechanisms ensure that the norm is acquired and internalized. Internalization refers to changing the initial agent’s behavior to reflect the newly acquired norm. This chain of transmission, compliance and internalization of norms is named emergence.

The emergence sub-process continues until the norm is actually acquired, internalized and retransmitted by a sufficiently large number of agents in a population. At this point, the potential norm becomes a *de facto* norm, however, if a norm does not make sense anymore in the future, it is forgotten. Moreover, new conditions may arise motivating the creation of new norms and then the cycle repeats itself.

²Simulation Videos: <https://ourarchive.otago.ac.nz/handle/10523/1790>

V. DISCUSSION

Table I shows the comparison between the afore mentioned processes taking into account the criteria for the number of stages, which stage is given greater emphasis, and also the names given to early, intermediate and final stages of each process life cycle in order to clarify the naming differences.

Finnemore & Sikkink [23] propose a process in three stages where norms are created by a group of entrepreneurs that attempt to persuade some leaders to follow them. It is based on a convincing mechanism in order to reach a threshold (*tipping point*) beyond which the leaders will be responsible for the spreading of that norm within that society. The norm is then transmitted by an imitation-based cascading mechanism until members of the society start to accept the norm without questioning it.

Savarimuthu [24] gives more emphasis on the identification step of the norm by individuals in a society who try, through observation, to learn the expected behavior in specific situations within that social group. A norm is said to have been assimilated when it starts to be followed by a significant number of agents in the society.

Finally, Hollander [11] identifies an evolutionary trend in norm life cycle, such as a greater emphasis is given on the emergence subprocess. For this author, norms are created, transmitted, enforced and eventually internalized, and even forgotten, in some situations. Moreover, new conditions may lead to the emergence of another norm that will go through the same cycle.

In the comparative table, this author's stages, are within quotation marks because, after wrapping up the stages of transmission, enforcement and internalization into the emergence stage, it also results in a three-stage cycle (*Create, Emergence and Forget*).

Table I. COMPARATIVE TABLE

	Finnemore & Sikkink [23]	Savarimuthu [24]	Hollander[11]
Number of stages	3	3	"5"
Emphasis	Tipping Point	Identification	Emergence
Early stage	Emergence	Formation	Create
Intermediate stage	Cascade	Propagation	Emergence
Final stage	Internalization	Emergence	Forget

VI. CONCLUSION

This paper has presented an analysis of norm processes in natural and artificial societies, pointing out some differences among them. It was observed the need of a better systematization of activities and of the stages of norm generation and evolution. It was also noticed a certain degree of ambiguity about the taxonomy of the different life cycle stages as well as of the used techniques. Moreover, the aforementioned work does not address a possible integration of norm life cycle to processes and methodologies for system development.

As further work, we intend to propose a generation and evolution process for norms, composed of specific methodologies and techniques for each stage, which can be integrated into processes and multi-agent systems development methodologies.

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