British Journal of Applied Science & Technology
12(4): 1-15, 2016, Article no.BJAST.21653
ISSN: 2231-0843, NLM ID: 101664541

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A Norms Decay Framework in Open Normative Multi-agent Systems

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Authors' contributions

This work was carried out in collaboration between all authors. All authors read and approved the final manuscript.

Article Information

DOI: 10.9734/BJAST/2016/21653
Editor(s):
(1) Wei Wu, Applied Mathematics Department, Dalian University of Technology, China.
Reviewers:
(1) D. V. Kodavade, DKTE Society's Textile & Engg Institue, India.
(2) Hui Li, Icahn Medicine School at Mount Sinai, New York, USA.
Complete Peer review History: http://sciencedomain.org/review-history/11671

Review Article

Received 27th August 2015
Accepted 16th September 2015
Published 5th October 2015

ABSTRACT

In open normative multi-agent systems, norms are created dynamically. Some of these norms emerge and persist due to their benefits and strength. While other norms emerge for a short period of time, then vanish due to several reasons that lead to loss in their benefit or strength. Each norm of the created ones might have positive, negative, or neutral consequences on the system. Norms decay refers to the case in which a norm is not practiced or adopted by any of society's members, and eventually deleted and forgotten. In this paper, we analyze the concept of norms decay and introduce a framework that contains the cases of norms decay which are conceived from the literature. The proposed framework contains three cases of norms decay which are: Norms Removal, Norms Disappearance, and Norms Collapse. The first case needs an intervention from a powerful authority, while the latter two cases happen when society members stop adopting or violate a norm.

Keywords: Norms; norms decay; norms removal; norms disappearance; norms collapse; normative multi-agent systems.

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1. INTRODUCTION

The norm concept has a variety of meanings and definitions due to its ambiguity. These meanings and definitions share the same general idea which can be summarized as follow: a norm is a mechanism for organizing and controlling a society [1,2]. Thus, social norms are of different levels of complexity. The simplest social norm is defined as: "Do X, or, Do not do X" [3]. Based on this definition, we can conclude that a norm is an imposition or prohibition of an action or behavior [4].

Artificial intelligence research employs norms in the process of regulating software entities life, and to regulate the interactions among them. This employment developed to deal with coordination and security issues in multi-agent systems where an agent is considered as a software entity [1].

Each norm in a society has a lifecycle. There are numerous models of norm lifecycle. Most of these models start with creation or generation process. Then the norm goes through different processes such as: spreading, emergence and stability [5]. Some researchers suggested that a norm lifecycle final process is removing it from agents' cognitive structure or belief base [6-9] While other researchers suggested that a norm lifecycle final process consists of two possibilities: a norm either evolve due to its importance and power, or decay due to invalidity or obsoletion [5,10]. These two processes might be applied after a long time of norm stability.

The literature provides a huge number of research work on all norm lifecycle processes but the last phase which could be either evolution or decay. Norm's evolution or decay has been discussed thoroughly in social science, but there is no concrete model in computer science for them yet [4]. Our concentration in this paper is on modeling norms decay and its cases which are: norms removal, norms disappearance and norms collapse.

In this paper, we address the issue of norms decay by dividing it to three main cases: Norms Removal, Norms Disappearance, and Norms Collapse. Norms removal is applied when a norm is causing negative consequences on a society, and in the same time it is still practiced because it is supported by strong beliefs. This case requires society authority intervention in order to force agents to remove this norm because practicing such norms prevents a society from evolution and might destroy it [4]. The other two cases, which are: disappearance and collapse, happens due to society agents' actions. Norms disappearance happens when society's majority abandon the norm due to its benefit decay, among other cases [10]. While collapse case happens when society's agents' violate the norm due to the conflict between their own goals and norm constraints, in this case the violation cost should be less than violation sanction [10].

The issue of norms decay in this paper is discussed in open normative multi-agent system. An open multi-agent system main characteristics are as follows: 1) Having heterogeneous agents, 2) Agents are not trustworthy, 3) Agents goals might conflict, and 4) A high possibility of non-accordance with specifications [11]. Agents in these systems are autonomous, which requires regulations or soft shared agreements. Norms are a solution for this requirement [1].

The rest of this paper is organized as follow: in the second section, a review about social norms and their classification is presented. Section 3 contains a review about intelligent agents, multi-agent systems, and agents' communication. In section 4, the merging of social norms and multi-agent systems is described; these systems are called normative multi-agent systems. In the same section, the used type of normative multi-agent systems is reviewed and described; it is called Open Normative Multi-Agent Systems. After that, in section 5, a similar system is described, which is called EMIL. Section 6 contains the proposed framework and its explanation. Lastly, section 7 concludes the paper.

2. SOCIAL NORMS

Social norms are introduced by Hollander and Wu [12] as: "A norm is any behavioral rule that is considered valid by the majority of a population". From this definition, it can be said that norms are set of soft rules that regulate society individuals' behavior among each other. Based on this explanation, norms will not make any sense for a single individual who is living alone, this individual might be ruled or seduced by physical features, but this kind of behavior is called habits not norms [5].

Norms regulate relations between individuals or groups of individuals through an aspect called social reality. In general and simple words, social reality represents a reality that is created by and only by a kind of joint agreement between individuals in certain society [1]. Accordingly, social reality cannot exist in an empty society; there should be at least two independent individuals for the joint agreement to create social reality. Now we can conclude that norms are part of social reality. Thus norms are also created by joint or mutual agreement. Because of that, norms nature is not entirely fixed; it is malleable by mutual agreement. This leads to the fact that norms has two parts: first part is so-called a core part which is relatively stable, the other one is so-called penumbra which is malleable or flexible [5].

There are three main types of norms [13]:

1. Constitutive norms: this type defines a system of actions and an individual's membership in it.
2. Regulative norms: this type describes the expected contributions to the social system.
3. Distributive norms: this type defines how to allocate rewards, costs, and risk within a social system.

The listed three types are illustrated in Fig. 1.

Therborn [14] also distinguished non-institutionalized normative order that constitutes personal and moral norms, and institutions of a social system defined as a closed system of norms.

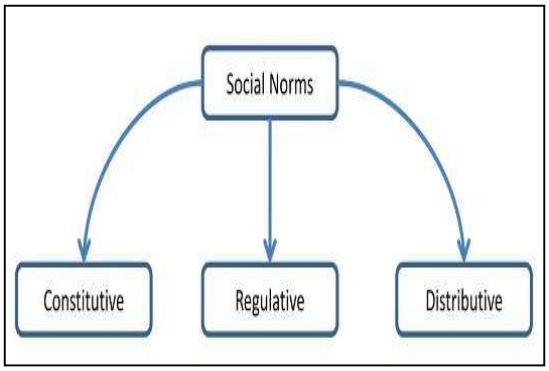

Fig. 1. Norms types

3. INTELLIGENT AGENTS AND MULTI-AGENT SYSTEMS

In the following sections, a review about intelligent agents, multi-agent systems, and agent communications is introduced. These concepts are important in introducing norms decay framework because one of the most important basis of norms decay is the communication between society agents.

3.1 Intelligent Agent

According to Wooldridge [15], it is challenging to answer the question what an agent is. In general, software agents can be defined as entities that function continuously and autonomously in a particular environment that is often inhabited by other agents and processes [16]. The simplest form of agent can be thought of subroutines that have some sort of persistent control and they are able to communicate with peers by some agent communication language [17].

Some researchers define an intelligent agent as having properties that normally applied to humans such as knowledge, belief, desire, intention, and obligation [18,19], which is also known as intentional notion. Other researchers attribute intelligent agents with emotions in the BDI architecture [20,21].

Agents can be defined as having the following properties [15]:

1. Autonomy: agent operates without direct human intervention and may have some kind of control over their action and internal state.
2. Social ability: agents interact with one another and possibly human.
3. Reactivity: agent perceives its environment and responds to the changes in a timely manner.
4. Pro-activeness: agent does not simply act in response to its environment but to be able to have goal-oriented behavior by taking initiative.

The paradigm of agent shifted from command-oriented in second generation language (Assembler), to function-oriented in third generation language (C, Pascal), then to objected-oriented (C++, Java), and finally to role/goal-oriented (Agents). Fig. 2 shows the paradigm shifts.

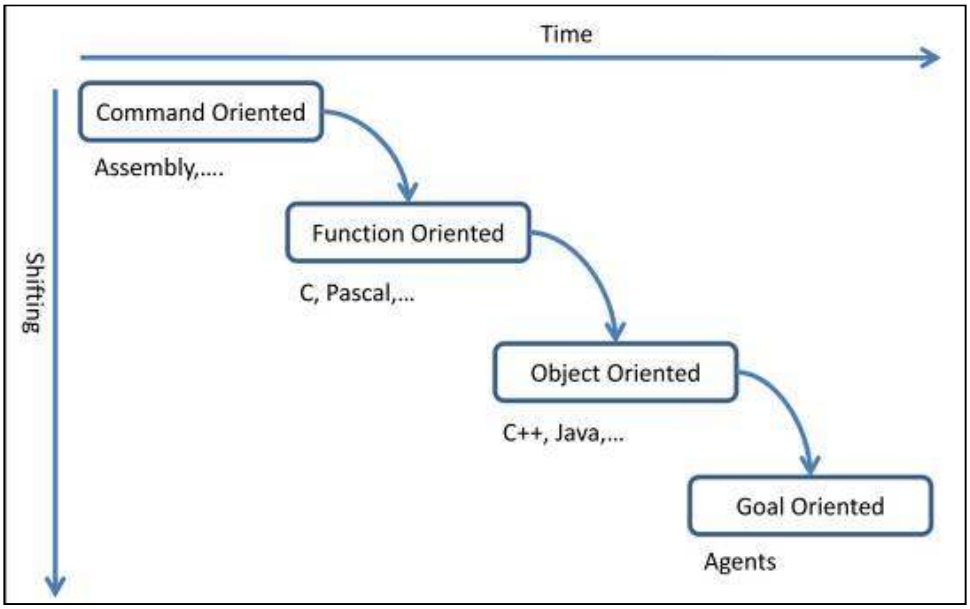

Fig. 2. Paradigm shifting of programming languages

3.2 Multi-agent Systems

Agents can co-exist in an environment forming a multi-agent system (MAS). The MAS offers various benefit as described in [22], some of them are as follows:

- Inherently complex problems: when a problem is too complicated to be solved by one single agent, well-designed intelligent agents ensure that every circumstance is handled in an appropriate manner even though it may not have been explicitly anticipated.
- Inherently distributed problems: where data and information are distributed in different physical locations at different times. A system with agents running concurrently can provide answers to such problem.
- Robustness and reliability: there is no single agent holding vital role; if one agent fails, others can take up its role. This ensures that the system would degrade gracefully if one or more agents fail.
- Scalability: MAS provides option for adding more agents to improve system capability.

In a MAS environment, agents interact with one another. Consequently, effectively communication protocols are needed. The following list some of these protocols [15,23]:

- Contract nets: analogy of contract bidding process. Manager broadcasts a task to be completed, an agent requests to take up the task, manager assigns the task to a selected agent and communicate with him until task completion.
- Cooperative problem solving: this communication framework consists of four stages:

  1. Recognition: agent may have tasks they cannot complete themselves and other agents recognize the potential for cooperation with it.
  2. Team formation: agent realizes the chance for cooperation and solicits further assistance. Once successful, they form a team with joint commitment to complete the tasks.
  3. Plan formation: the group of agents negotiates a plan to achieve the common goal.
  4. Team action: the agreed plan is being executed.

- Shifting matrix management: the model can be summarized in a six-stage framework:

  1. Goal selection: Agents select task they want to perform based on their initial mental state.

2. Individual planning: Agents select a way to achieve their goals. If the goal is common with other agents, they can decide to pursue the goal together or in isolation.
3. Team formation: Agents that can cooperate together form a team. Team formation requires an agreed code of conduct, a basis for sharing resources, and a common measure of performance.
4. Team planning: Agents put together a plan on which task to be executed by whom.
5. Team action: The plan is executed based on the agreed code of conduct.
6. Shifting: After the goal is achieved, the team is disbanded, and then the agents shift its goal, role and position. Each agent updates its probability of team-working with other agents, depending on whether or not the completed team-working experience with that agent was successful.

Fig. 3 shows multi-agent system architecture.

3.3 Agents' Communication

Agents can be designed by different people, can reside in distributed systems or in a single system, but they must be able to communicate with one another. The consequence of this is a standardized structure of messages or language that must be understood by all agents in that environment [17].

According to Cohen and Levesque [9], a language is needed for inter-agent communication to convey messages to other agents, to enlist for their support in achieving goal, to report progress of success and failure, to refuse task allocation, etc. Moreover, agents interact with human from time to time e.g. receiving a task from human. As such, it is crucial that the functions offered by the communication language are common across language of agents and language that people used to communicate with them. This language is known as Agent Communication Language (ACL) [9,22].

One of the ACLs that is most developed is the Knowledge Query and Manipulation Language (KQML). KQML can be thought of as a communication language that is able to facilitate high level cooperation and interoperation among agents. A typical KQML message includes the following key components [24]:

- Performative: describing the purpose of message e.g. cancel, do, test, validate, etc.
- Sender: identity of agent who sends message.
- Receiver: identity of agent who receives message.

Language: the language used in the content of message. Programmer can use any programming language to convey the message or employing KQML overall form of message.

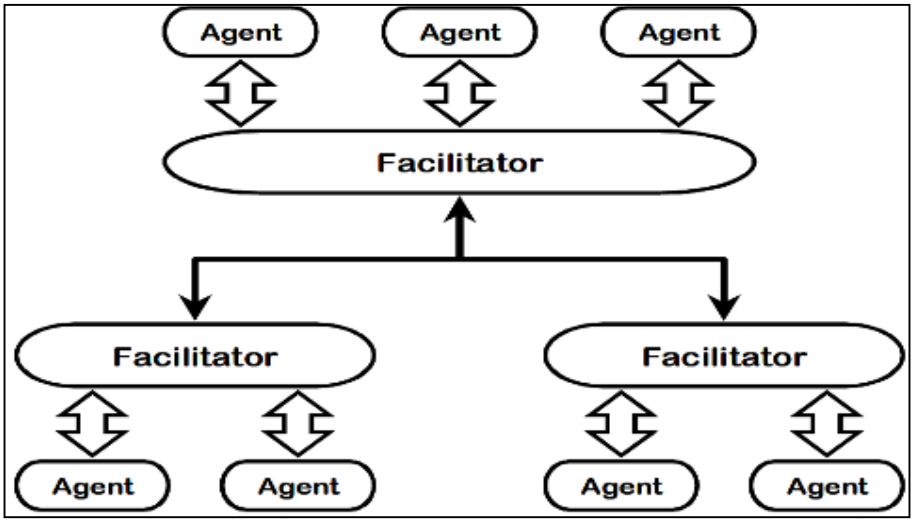

Fig. 3. MAS architecture

KQML as message contains a dialogue between sender and receiver. KQML also supports delayed and conditional operations, request for bid, offers, promises, etc [17].

The KQML message structure consists of three layers: content, message and communication layers. The content layer contains the actual content of the message specified in any language. The message layer consists of the set of performatives provided by the language. The use of a particular performative specifies whether the content is a query, an assertion or any of those defined in the categories. The communication layer consists of low-level communication parameters, such as sender, receiver, and message identities. A typical KQML message format is as follows:

```
(tell
: content “cost(bt, service-4, £5677)”
: language standard_prolog
: ontology bt-services-domain
: in-reply-to quote service-4
: receiver customer-2
: sender bt-customer-services)
```

KQML has several features that makes it the most flexible agents' communication language. These features can be categorized as follow [18]:

- Form: KQML messages are of declarative type and they are represented as a linear stream of characters. This format makes the process of reading and handling messages an easy process. Parameters inside the message are associated with their values in pairs which ease the parsing process, and ease the process of adding new parameters.
- Content: a message in KQML is divided into three layers: i) Content layer, ii) Message layer and iii) communication layer. KQML messages are inattentive of the contents they carry, the important issue is to deliver the contents to the defined destination. This feature provides a kind of privacy to the exchanged messages.
- Implementation: KQML can be implemented using any programming language, the intended software should follow all the criteria of KQML scheme. A software that implements KQML should provide a facilitator agent, which is responsible of messaged delivery. This feature gives a huge flexibility to multi-agent systems development.
- Networking: KQML has been designed to work with multiple transport mechanisms, and implementations have been done that use TCP/IP, SMTP (email), HTTP and CORBA objects to carry messages. Add to that, KQML agents can be addressed using symbolic names. KQML messages can be sent point-to-point; multicasting and broadcasting are possible in any of the transport mechanisms through the use of facilitator class agents. KQML allows both synchronous/asynchronous interactions and blocking/non-blocking message sending on behalf of an application, through assignment of appropriate values for those parameters in a KQML message.
- Environment: it is possible to use any transport protocol, such as HTTP or SMTO or TCP/IP, to transfer KQML messages. KQML messages are inattentive to their contents, therefore there are no restrictions on the contents language. The existence of facilitators in the KQML environment can provide the means for knowledge discovery in large networks, especially if facilitators can cooperate with other knowledge discovery applications available in the World Wide Web.

4. NORMATIVE MULTI-AGENT SYSTEMS

A normative multi-agent system is formed from a set of normative agents. A review about normative agents, normative multi-agent systems, and open normative multi-agent systems is introduced in the following sections.

4.1 Normative Agent

Normative autonomous agent is an agent having behaviors that are shaped by obligations it has to comply with, prohibitions that limit the kind of goals it can pursue, social commitments that are created during its social interactions, and social codes whose fulfillment represents social satisfaction for the agents [25]. Castelfranchi et al. [26] believe that such agent is able to take into account the existence of social norms in its decision (e.g. to follow or violate a norm), and able to react to violations of the norms by other agents [26]. They proposed to have deliberative normative agents that have explicit knowledge about the enacted norms in multi-agent environment and can make a choice whether to obey the norms in specific areas.

4.2 Normative Systems

Boella et al. [27] define normative systems as: “A systems in the behavior of which norms play a role and which need normative concepts in order to be described or specified.”

The term "Normative" denotes conforming to or based on "Norms". Norms emerged in human society as a mechanism to guide individuals with different self-interest to co-exist and work together in harmony [28].

4.3 Normative Multi-Agent Systems

Normative multi-agent systems (NMAS) have been defined as MAS that use norms as a mechanism for persuading autonomous and heterogeneous agents to behave according to the stated social order [13]. Therefore, NMAS define norms, which are immaterial entities that exist thanks to their acceptance by the society members, in order to avoid conflicts and ensure social order.

Normative multi-agent systems can be considered as the intersection of normative systems and multi-agent systems. By integrating norms and individual intelligence, normative multi-agent systems present ideas for a model of human and artificial agent cooperation and co-ordination that could be potentially exploited for research into areas of group-decision-making, multi-agent organizations, regulated societies, electronic institutions, and secure multi-agent systems [5].

In normative multi-agent system, multi-agent system exists together with normative systems in which norms are represented explicitly [29]. In one hand, agents can decide whether to follow the norms, on other hand normative system specifies how agent can modify the norms and to what extent [30].

For the purpose of this study, we concur with the definition of a normative autonomous agent by López et al. [31] as: "An autonomous agent that has adopted some norms (norm instances) and has decided which norms to comply with (intended norms) and which norms to reject (rejected norms)".

The characteristics of norms in NMAS can be summarized as follows [31].

1. Norms tell agents how to behave, i.e. prescriptiveness.
2. Norms guide many existing agents to interact with one another, i.e. sociality.
3. When there is a conflict of interest between norms and agent’s self-interest, socially acceptable mechanism force agents to comply with norms, i.e. social pressure.

4.4 Open Normative Multi-Agent Systems

Open systems are characterized by the heterogeneity of their participants, non-trustworhty members, existence of conflicting individual goals and a high possibility of non-accordance with specifications [11]. The main feature of agents in these systems is autonomy. It is this autonomy that requires regulation, and norms are a solution for this requirement. In these types of systems, problems are solved by means of cooperation among several software agents [32].

Norms prescribe what is permitted, forbidden, and mandatory in societies. Thus, they define the benefits and responsibilities of the society members and, as a consequence, agents are able to plan their actions according to their expected behavior. However, norms are not only regulations, but they also establish social institutions which give rise to new types of facts [33]. In general, processes that require coordination and cooperation also require the definition of norms that control these interactions [34].

In open systems, the regimentation of all actions can be difficult, but sometimes it is also inevitable or even preferable to allow agents to violate norms [35]. The reasons behind desirability of norm violations are either that it is impossible to take a thorough control of all their actions; or agents could obtain higher personal benefits when norms are violated; or norms may be violated by functional or cooperative motivations. All these situations require norms to be controlled by enforcement mechanisms [1].

To form an open society the requirements are that [11]:

- There is a need to make the organizational and legal elements of the multi-agent society externally visible, and to provide institutions and formalizations of agent interactions to protect agents from actions of other agents.
- Open societies should be neutral with respect to the internal architecture of their members.

- In a society, communication and conformance of behavior are at least as important as intelligence.

In Open Normative Multi-Agent Systems, internal states of agents are not accessible. Therefore, norms cannot be imposed as agent beliefs or goals, but they have to be implemented in the society by means of control mechanisms [11].

5. NORMS DECAY IN THE LITERATURE

The literature provides a very limited number of research work that is related to norms decay. In most research work, researchers mentioned that norms decay is important, or it is a stage of norms lifecycle.

A research work by Andrighetto et al. [36], which is called Emergence In the Loop (EMIL), this project is about modeling norms innovation in a society, it also models the emergence and decay of social norms. In this work, decay is defined as "The process by means of which a given norm decays leaving no trace in the mind". They described norm as any other object representation, norms may be acquired, modified and lost. Norms may disappear under the effect of cognitive and non-cognitive mechanisms.

According to EMIL researchers, there are two cases of norms decay:

- Norm-revision: reasons leading to a given input being recognized as a norm are found no more adequate. This may occur with:
    - Perceived error in previous recognition: observer is led by the state of the world currently perceived (current behavior of the source) to reconsider and revise previous interpretations.
    - Perceived change in the current state of the world: for example, observer perceives a modification in the source's behavior.
    - Simple forgetting: generally associated to a gradually reduced salience of the norm, no longer fit to a changing environment.
- Norm-revocation: the reasons that led adopter to accept a norm are found no more adequate. Again, this includes:
    - Revised norms: decider finds the norm to be no more compatible with decision-based modifications of its normative board.
    - Modified personal goals: reasons for adopting the norm are insufficient if the decider's goals have changed in the meantime. This may also be due to a non-cognitive cause, such as the normal course of life.

Norm invocation implementation requires more or less complex mechanisms. A simple solution is to include a forget rate, among the agent parameters: if the salience rate of a norm remains very low for a certain period of time, then the norm is bound to decay from the agents' normative board. However, more interesting solutions for norm revision and revocation exist. Indeed, norm revision is already included in the norm recognition process, as this is a non-linear process by means of which a given input (either a prescription or a regularly observed behavior) is analyzed [36].

6. THE PROPOSED FRAMEWORK OF NORMS DECAY

Norms decay definition in Oxford Dictionary is: "The process of declining in quality, power, or vigour" [37], this means that decay process might happen by external or internal power. The literature provides three cases for norms decay which are: Norms Removal, Norms Disappearance, and Norms Collapse. These three cases can be categorized into two categories:

1) Norms decay by external authority interference: this category includes norms removal case only. In this case, a powerful authority, which has the ability to apply sanctions and rewards, should interfere to remove a negative norm. Negative norm means that a norm is causing negative consequences on the society, yet society members still practice it because it is supported by strong beliefs. According to this description, society members continue practicing a strong negative norm although it is affecting them negatively, or affecting the environment. Authority interference to remove such norms happen in three stages, which are applied after detecting the negative active norm:

i. Impact the beliefs that support the norm subject to removal: in this stage, the authority clarifies the negativity of a norm to society's members. In the same time, the authority gives the replacement belief to the ones which support the negative norm.
ii. Authority receives behavioral changes reports from society's members: in this stage, society members inform the authority about their beliefs change. This is important to reach collective belief change state.
iii. Impact society's members' actions: after reaching collective belief change, authority force society members to stop practicing the norm subject to removal. This is done using several techniques; one of them is to impose sanctions on norm practicing.

2) Norms decay by society agents actions: this category includes norms Disappearance and norms Collapse. Society's members' actions towards a norm can be either to Adopt, Abandon, or Violate a norm. Norm adopting is applied when a society's member gains benefits from a norm, or the norm is supported by strong beliefs as mentioned earlier, adopting a norm keeps it active in the society. While norm abandon happens when a norm losses its benefits to members, or a new norm with higher benefits emerges. Abandoning a norm from the majority in a society leads to the disappearance of this norm. This is due to the fact that society members stick to norms with higher benefits than other norms. Norm violation leads to norm collapse. This action is taken when the benefit of violation is higher than violation sanction. In this case, society members violate a norm gradually. After some time, the norm collapse because the majority is violating it, and the authority cannot sanction them all.

Fig. 4 represents norms decay framework that contains norms removal, disappearance, and collapse.

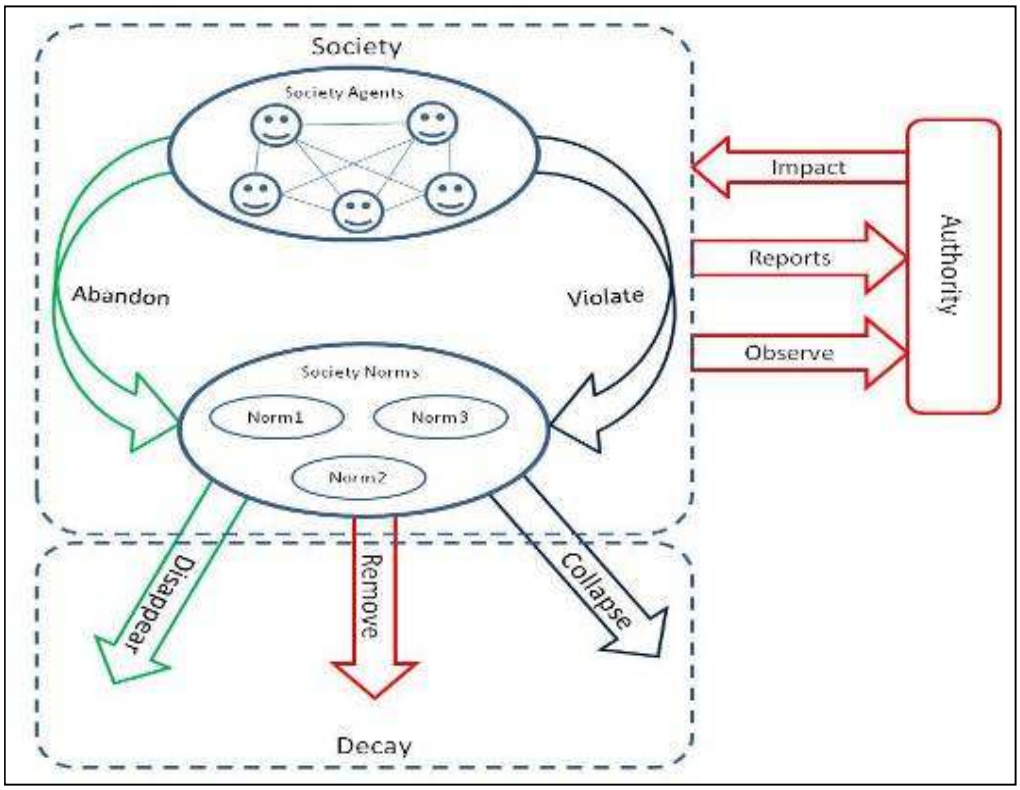

Fig. 4. Norms decay framework

Norms decay cases cannot be applied on one norm. This is because each case has different conditions to be applied. In order to illustrate norms decay in a clear scenario, we have to apply it on a society that contains a number of agents, an authority, and several services facilities. The agents in this society are either settlers or visitors. Settler agent means that this agent is a resident of specific society, and this agent is practicing all his activities inside the society. While visitor agent means that this agent is practicing a temporary activity in a society, visitor agent leaves the society after finishing his activity. The authority has enough power to monitor all norms practicing actions, it is also able to give rewards or apply sanctions on any agent. Services facilities include any facility that gives a service to society agents, like supermarkets or banks for instance, these service facilities send reports about norms practicing to the authority. In this paper, we use supermarket service facility as a domain to illustrate norms decay cases. A supermarket is a large self-service store selling foods and household goods. In this environment, agents practice several norms, the practiced norms activities are sent to the authority which controls the whole society. A supermarket also has local management which takes decisions that affects the supermarket only, not the society. This management is also required to follow society authority orders.

In the following sections, we explain the steps of each case of norms decay along with a model that illustrates those steps.

6.1 Norms Removal

Norms removal refers to the action of taking away a norm that causes negative consequences on a society when it is being practiced. Norms removal is applied on negative active norms in a society. The steps of norms removal is illustrated in Fig. 5. The authority cans observer norms practicing activities through the services facilities in a society (1). The received observations are filtered and analyzed in order to detect the consequences of norms practicing (2). The analysis results are stored in special cognitive structure in order to be used by the authority. In case of detecting a negative norm, this norm should be removed. Norms removal is done by impacting the behavior of society agents (3). Behavior impact is done in two main stages which are: i) Beliefs change, and ii) Actions change. Those two stages are adopted from the work of Bicchieri et al. [38]. The authority agent starts to impact society agents' beliefs by making them aware of the negative consequences that a norm practicing is creating (4). In the same time of impacting agents' beliefs, authority agent is receiving reports about the level of awareness that society agents reached (5). When reaching a high level of awareness, which is called collective belief change, authority agent starts with actions impact (6). Eventually, collective action level is reached. This means that all agents in a society stops practicing a norm. When reaching collective action level, the norm is considered to be removed (7).

An example for this case in the chosen domain, which is a supermarket, is buying non-recyclable items. Agents are used to buy non-recyclable items from a supermarket because these items are cheaper than recyclable ones. The authority of this society detected that this norm is causing negative consequences on the environment, negative consequences are the increase of non-recyclable trash which gives bad appearance and it increases the cost of removing it. In this case, the authority decides to remove this norm. It starts with changing the beliefs of agents by making them aware of the consequences of buying non-recyclable items. In the same time, the authority is receiving feedback about the beliefs change from society agents. When reaching a high level of beliefs change, this means that the majority changed their beliefs and ready to change their actions, the authority sends an order to the supermarket management to remove all non-recyclable items and replace them with recyclable ones. At this point, the norm of buying non-recyclable items has been removed.

Norms removal can be formalized as follow:

- If *NR* is the norms removal; n is the norm subject to removal, *AM* is the majority of society's agents; *CBC* is Collective Belief Change; *CA* is Collective Action, then,

$$N_R: Remove\ (n) \Leftrightarrow Negative(n) \wedge CBC(n, A_M) \wedge CA(n, A_M) \quad (1)$$

This means that a norm is removed if and only if three conditions achieved: i) The norm is negative, ii) Majority of society's agents changed their beliefs towards this norm (Collective Belief Change), and iii) Majority of society's agents changed their actions towards this norm (Collective Action).

- If *n* is a norm; *E* is the environment that a society lives in; *AM* is the majority of society's agents; then:

$$Negatice\ (n) \Leftrightarrow Harm(n, E) \vee Harm(n, A_M) \quad (2)$$

This means that a norm is considered negative if its practicing harms the environment or harms other agents.

- If n is a norm; *B1* is the set of beliefs that supports this norm; *B2* is the new set of beliefs that agents should adopt; AM is the majority of society's agents; a is an agent in the society; then:

$$CBC: \forall\ a \in A_M: Delete(n, B_1) \wedge Adopt(n, B_2) \quad (3)$$

This means that Collective Belief Change happens when the majority in a society deletes the old beliefs that supports a negative norm and adopt new beliefs that supports removal of the negative norm.

- If *n* is a norm; *AM* is the majority of society's agents; a is an agent in the society; then:

$$CA: \forall\ a \in A_M: \neg Adopt(n) \quad (4)$$

This means that Collective Action happens when the majority in a society stops adopting a norm.

6.2 Norms Disappearance

Norms disappearance is the result of abandoning a norm from the majority in a society. Abandoning a norm means not practicing it without being sanctioned from the authority. Fig. 6 illustrates the steps of norms disappearance. Norm abandoning happens when it loses its benefit. An agent checks the benefit of a norm (1). If the norm still gives benefit when it is being practiced, the agent maintains it (2a). Otherwise, if the norm lost its benefit when it is being practiced, the agent abandons it but keep it in his cognitive structure (2b). The agent checks the practicing activities of this norm in his society, if the majority abandons it (3a), then the norm is considered as disappeared (4), and eventually the agent can delete it from his cognitive structure (5). Otherwise, if the majority is still practicing it (3b), the agent keeps the norm in his cognitive structure for future possibility of practicing.

Pay by cash norm illustrates norms disappearance case in the chosen domain, the supermarket. For a long time, customers used to pay by cash; this norm causes several problems, like forgetting to bring enough amount of money, or losing it, or having the risk of getting robbed. With technology becoming more advanced, new methods of payment has been developed, like credit cards or even pay by mobile phone. Customers' starts to adopt the new norm of payment, by credit card or mobile phone, because its benefits are higher than the old norm, pay by cash. The two main benefits are reducing the chance of being robbed, and carrying less number of items in the wallet. Eventually, after some time, the old norm disappears from the society and, as a result of disappearance; agents delete it from their cognitive structure and keep the new norm.

Norms disappearance can be formalized as follow:

- If *ND* is the norms disappearance; n is the norm that disappeared, *AM* is the majority of society's agents group; then,

$$N_D: Disappear(n) \Leftrightarrow \neg Benefit(n, A_M) \wedge \neg Adopt(n, A_M) \quad (5)$$

This means that a norm disappears if and only if two conditions achieved: i) The norm is not beneficial for the majority of society's agents anymore, and ii) The majority of society's agents stopped adopting it.

6.3 Norms Collapse

Norm collapse is the case of norm vanishing from a society due to agents' violation of this norm and violation sanction decay. Fig. 7 shows the steps of norms collapse. An agent checks the benefit of violating a norm, and the sanction of violation (1). If the benefit gained from violating a norm is less than the sanction of this norm, the agent does not violate the norm and maintain it (2a). Otherwise, if the benefit of violation is more than the sanction of violation, the agent violates the norm and gets the benefits he wants (2b). Even when the agent violates the norm, it keeps it in his cognitive structure, and in the same time checks if the majority is violating the same norm (3). If the agent observed that the majority are not violating the same norm (4a), he maintains the norm. Otherwise if the majority is violating the same norm (4b), the norm is considered as

collapsed (5). Eventually, the agent can deletes it from his cognitive structure (6).

A norm that illustrates the case of norms collapse in the chosen domain is putting price label on grocery before going to cashier. Normally, customers have to weigh and take price label for the grocery they buy before going to cashier. This process is carried out by a special employee, and it is done normally near the grocery place in the supermarket. The cashier might weigh and price one item in case the customer forgets to do so. Some customers start to violate this norm by bringing several items without pricing to the cashier. If the cashier refused to weigh and price them, customers leave what they bought, and in this case, the supermarket loses. After violating this norm from a number of customers, supermarket management decides to move the weighing and pricing process to the cashier instead of its previous place. We notice that the norm of pricing grocery before going to the cashier has collapsed under the power of customers' violation.

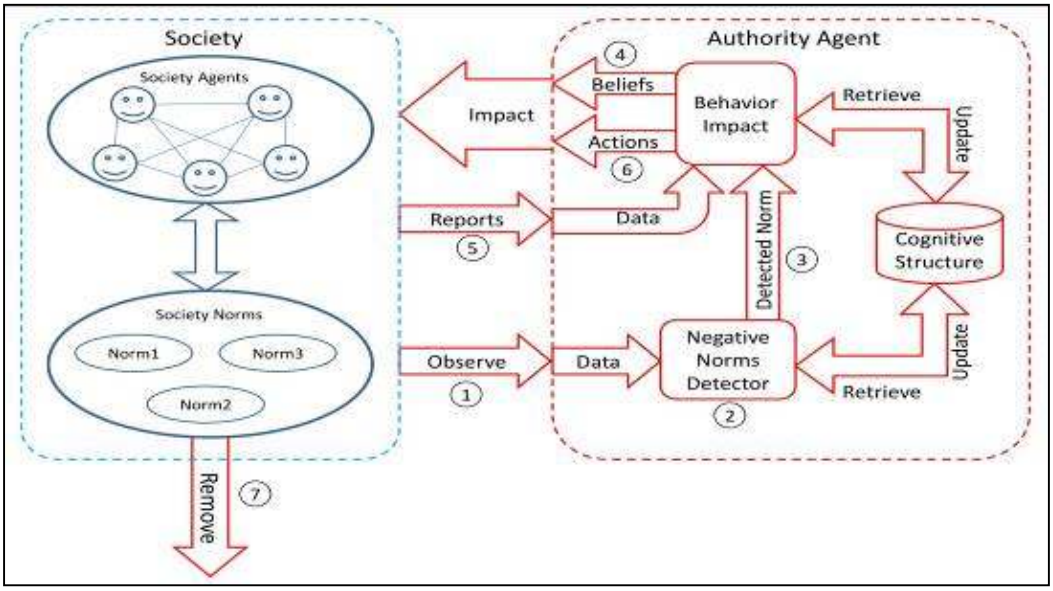

Fig. 5. Norms removal steps

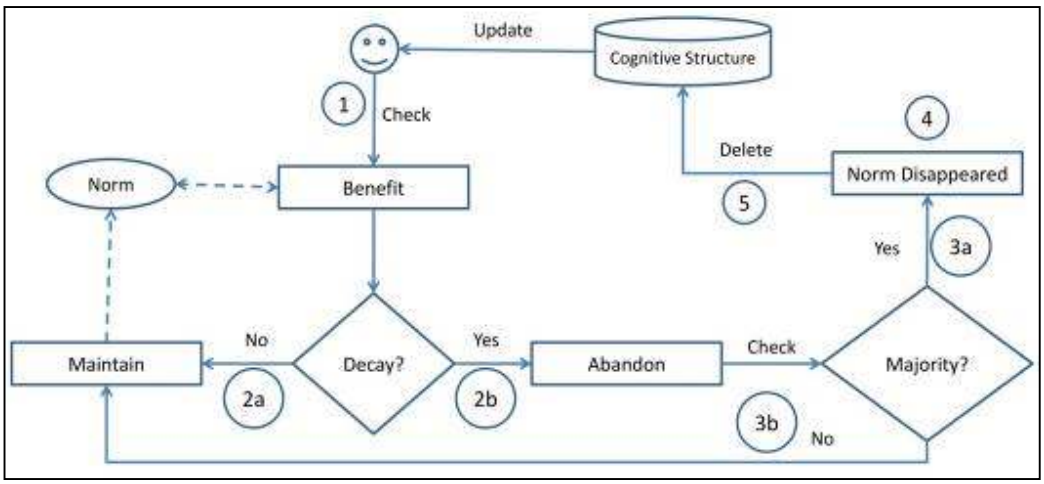

Fig. 6. Norms disappearance steps

Norms collapse can be formalized as follow:

- If *NC* is the norms collapse; n is the norm that collapsed, *AM* is the majority of society's agents group; then,

$$N_C: Collapse(n) \Leftrightarrow \neg Benefit(n, A_M) \wedge (Sanction(n, A_M) < VBenefit(n, A_M)) \wedge Violate(n, A_M) \quad (6)$$

This means that the a norm collapses if and only if three conditions achieved: i) The norm is not beneficial for the majority of society's agents anymore, ii) The sanctions of violating this norm is less than the benefit of violating it, and iii) The majority of society's agents are violating it.

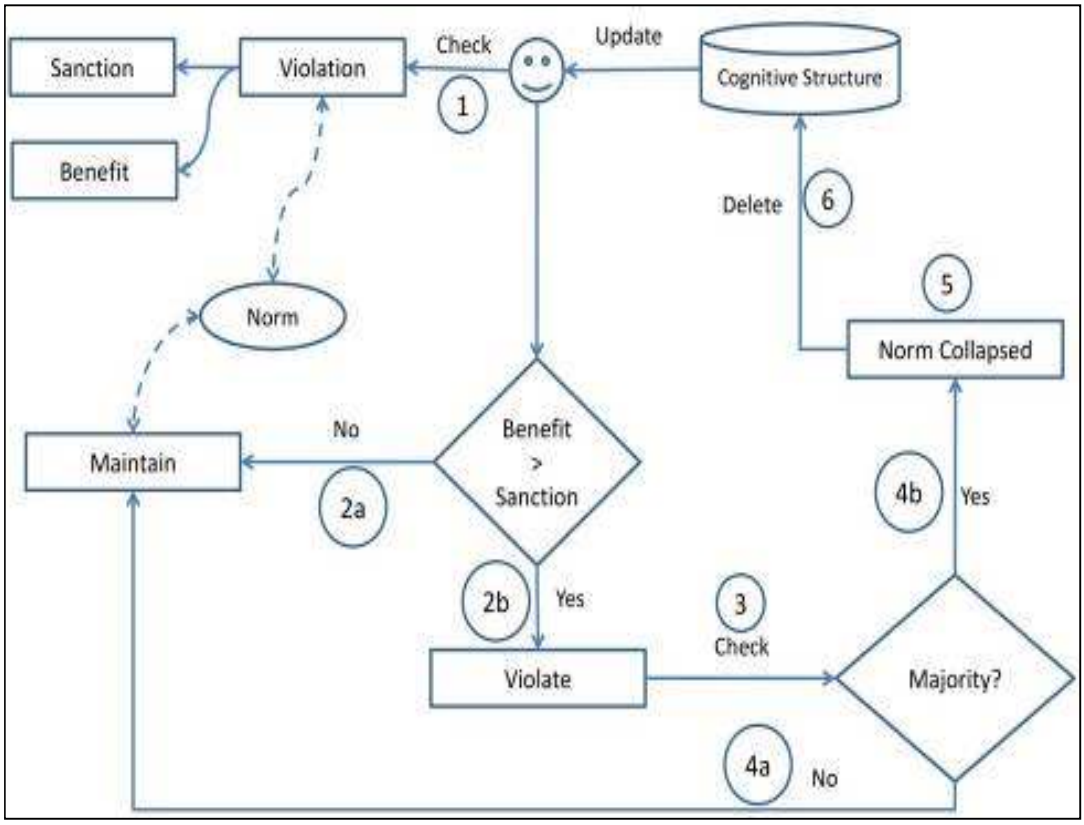

Fig. 7. Norms collapse steps

7. CONCLUSION

In this paper, our research on norms decay in open normative multi-agent systems is presented. We observed from the literature two categories of norms decay: i) Norms decay by external authority interference, and ii) Norms decay by society agents actions. The first category has one case which is norms removal, while the latter one has two cases: norms disappearance and norms collapse. The literature of social science provides a description of norms removal only, we could not find any model of norms removal in social simulation or artificial societies. Although there is some work on norms disappearance and collapse in social simulation and artificial societies, but it is not a comprehensive work.

In our future work, we shall simulate each category and cases of norms decay.

ACKNOWLEDGEMENTS

This work is supported by the Exploratory Research Grant Scheme (ERGS) by the Ministry of Education Malaysia under the Grant Ref. No. ERGS/1/2013/ICT01/UNITEN/02/02.

COMPETING INTERESTS

Authors have declared that no competing interests exist.

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