# ANALYZING THE PRINCIPLES OF ISLAMIC JURISPRUDENCE FOR A NORMATIVE FRAMEWORK IN MULTI-AGENT SYSTEMS

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## INTRODUCTION

An appropriate starting point for synthesizing a normative framework from the principles of Islamic Jurisprudence is to study and analyze the concepts and semantics of those principles. *Fiqh* (in Arabic) is the study of Islamic Jurisprudence and refers to the knowledge that teaches the commands and prohibitions of Allah's Law contained in the *Quran* (the Final Testament), and its details in the *Hadith* (the traditions of Prophet Muhammad, Peace Be Upon Him). The Prophet was anointed to be a living example among mankind to prove that a human being can live happily in compliance with the laws of the Creator (Majeed 1990). The *Hadith* is a compilation of authentic reports on what and how the Prophet explained certain issues from which the discipline of *Fiqh* is derived. These principles are established to infuse order and promote compliance in actions that relate to mutual interactions between people and their interactions with the Creator.

In this paper, we propose a normative framework, as an extension to our earlier work (Ahmad et al., 2009), adapted from the principles of Islamic Jurisprudence (Majeed, 1990). The framework is implemented on a community of intelligent software agents, which are much less complex than humans based on such established principles of governance. We analyze the semantics of each principle in the Islamic Jurisprudence and develop a logical model of rules and norms to manifest the framework. The rules are modeled on the principles of obligation (*waajib*) and prohibition (*haram*) while the norms are based on the principles of recommended (*sunnah*), neutrality (*mubaah*), and disliked (*makrooh*). The conditions of obligation and prohibition are mutually exclusive and influence the execution of norms within the agent community. For example, a rational, intelligent agent would exercise its norms within the extent of its obligation and attempts to avoid encroachment into areas of prohibition. While agents are at liberty to violate the norms (i.e., exercising its norms in the disliked state), the framework's reward/penalty structure motivates a rational agent to execute its actions in more favorable states, for example in recommended or neutrality state.

The tenet (*rukn*) consists of valid and invalid principles to guide an agent in deciding its course of actions. The framework's concepts of valid and invalid actions further strengthen the execution of norms that relates to the quality of actions. A rational agent is aware of the consequence of its action if it fails to comply with the tenet. The side effect of all these outcomes manifests a significant improvement in agent coordination and subsequently improves the overall performance of multi-agent systems. With this framework, an agent is aware of its current states and is guided by the rules and norms. It is also aware of the rewards it gets if it does the right things and the penalties for doing otherwise.

A normative environment consists of an authority that imposes some obligation to a society in which agents as the implementers attempt to achieve a normative goal (Lacroix et al., 2008). Basically, the norms in this environment determine the agents' behaviors, which are socially enforced to achieve the normative goal. The obligation usually consists of tasks to be performed within certain durations. Such environment closely resembles those situations that are manifested by the principles of Islamic Jurisprudence.

The above deliberations point to the following questions, which this research attempts to address:

1. How should agents be guided to do something, given the current states of the environment?
2. How should the principles of Islamic Jurisprudence be formalized as a normative framework?

The remaining part of this paper proceeds in the following manner. Section 2 explores the related work and theory of normative systems, in which agents coordinate their actions autonomously in attempting to achieve some goals. Section 3 introduces the concepts and semantics of the principles of Islamic Jurisprudence. Section 4 proposes the logical model of the normative framework based on such principles. In Section 5, we present a validation experiment on the framework and discuss the findings. Finally, Section 6 concludes the paper.

## RELATED WORK

Norms are becoming an interesting area of research because they help to improve the predictability of a society. Norms result in coordination and cooperation among the members of a society. Norms are characterized by their prescriptiveness, sociality and social pressure. Norms incorporated in

an agent system could guide an agent (prescriptiveness) to behave in an environment where more than one agent is involved (sociality). Since it is always expected that norms conflict with the personal interests of some agents, socially acceptable mechanisms to force agents to comply with norms are needed (social pressure) (Castelfranchi et al. 1999).

Savarimuthu et al. (2010) suggest that a normative multi-agent system is organized to represent, communicate, distribute, detect, create, modify, and enforce norms, and to deliberate about norms and detect norm violation and fulfillment. Castelfranchi et al. (1999) argue that norms in normative systems are represented by mental objects entering the mental processing that interact with beliefs, goals, and plans. They suggest that a normative autonomous agent is able to take into account the existence of norms in its decision (either to follow or to violate a norm) and is able to react to violations of the norms by other agents. They propose deliberative normative agents that have explicit knowledge about the enacted norms in multi-agent environment and are able to make a choice whether to obey or violate the norms in specific situations. López et al. (2004) define a normative agent as an autonomous agent that has adopted some norms (norm instances) and has decided on which norms to comply with (intended norms) or to reject (rejected norms). They suggest that norms should drive the behavior of agents especially in those cases when such behavior might affect other agents. Meanwhile, Savarimuthu et al. (2007) define norms as behaviors that are expected by the members of a particular society.

Researches in normative multi-agent systems have proceeded with vigor and enthusiasm in this decade. Some of the concepts that have been proposed by researchers include attribution on mental attitudes to normative systems (Boella et al., 2003a); obligation and permission (Boella et al., 2003b); defining the role of a defender agent to fulfill the task of identifying violations and sanctioning them on behalf of a normative system (Boella et al., 2004a); formalizing the trias politica using the standard BDICTL logic for agent verification (Boella et al., 2004b); regulative and constitutive norms (Boella et al., 2004a); substantive and procedural norms (Boella et al., 2008); and a verification framework for normative multi-agent systems (Astefanaoei et al., 2008). Other researchers focus on construction of norms in institution, and formalizing relationship between norms and agent's behavior (Lacroix et al., 2008); and providing a specification of the desired overall normative system behavior (Kollingbaum et al., 2008).

Some of these concepts seem to exhibit rudimentary formalisms of norms in agent systems, while others seem to impose stronger notions of norms which could be construed as formal rules, e.g., (Lacroix et al., 2008).

We argue that such notions are too strong to be modeled as norms in agent domains. This is because while intelligent agents are obliged to behave according to their goals, they are not to be penalized at the same time. Consequently, some kind of soft rules or constraints must be put in place to enable their decision-making prowess, without losing focus on achieving their goals. They should be aware of the current states of their environments, and be cognizant of the rewards and penalties if they fulfill or violate the norms.

In our opinion, norms should not be simple static constraints on behavior or on decisions. An agent's goals and preferences, its decisions among conflicting goals, and its plans must be based on its beliefs and the prevailing norms. The agent should be able to intelligently violate the norms if it disagrees with them (Kollingbaum et al., 2008). Boella et al. (2003c) support this issue and claim that norms should be represented by soft constraints and used in control systems where violation can be detected. Such systems exhibit a closer semantics to social norms, rather than using hard constraints, which completely restrict norms violation.

Prior to complying with the norms, the agent must evaluate the positive or negative effects of these norms on its goals so that it knows what might happen to whatever decision it takes in a normative environment (Castelfranchi et al., 1999). It must also be able to anticipate whether its actions are violating any norms that are associated with its role in the environment. The agent can adopt a goal that does not consider a forbidden behavior as a violation and is not penalized by it. López et al. (2004) introduce the concept of reward for the agent when its normative goals are satisfied, or penalty when they are not.

Besides all the researches on norms and normative systems, little attention have been focused on norms internalization and regulation in software agents, especially on the implementation issues. Consequently, real world applications of those issues have yet to be seen in normative frameworks and systems. However, a few researchers have proposed norm-based frameworks in multi-agent systems. Our review indicates that most norms-based frameworks are based on the concept of obligation in which agents are obligated to comply with the norms unless situations dictate otherwise. Table 1 compares some of the features of these frameworks.

**Table 1:**
Features of Normative Frameworks

| Features | BOID (Broersen et al., 2003); BIO (Governatori & Rotolo, 2007) | KGP (Sadri et al., 2006) | OP-RND (Ahmad et al., 2009) |
|---|---|---|---|
| Belief | Yes | Knowledge | BDI Architecture, (Rao and Georgeff, 1995) |
| Desire | Yes | Goal | |
| Intention | Yes | Plan | |
| Obligation | Yes | Yes | Recommended, Neutrality, Disliked |
| Prohibition | No | Yes | Yes |

## THE PRINCIPLES OF ISLAMIC JURISPRUDENCE

Cognizant of the issues in normative systems, we propose a novel concept of norms and rules for normative multi-agent systems based on the principles of Islamic Jurisprudence adopted from the Islamic Law (*Sharia*), as another alternative to existing normative frameworks. Islamic jurisprudence (*Fiqh*) deals with the observance of rituals, morals, and social interactions based on the *Sharia*. We argue that agent behaviors and actions should be based on a comprehensive structure of established moral and social principles as demonstrated by the *Sharia*.

The principle objective of *Fiqh* as guided by the *Sharia* is to regulate reasoning and to guide jurists in their efforts at deducing the law from its sources (*Quran and Hadith*). The purpose of *Fiqh* is to help the jurists in obtaining adequate knowledge of the sources of *Sharia* and the methods of juristic deduction and inference. It also enables the jurists to ascertain and compare the strength and weakness in the reasoning process (Kamali 1998). *Fiqh* involves seven main principles (*hukm*), which are obligation (*waajib*), prohibition (*haaram*), recommended (*sunnah*), neutrality (*mubaah*), disliked (*makrooh*), valid (*sah*) and invalid (*batal*) (Majeed, 1990). We argue that obligation and prohibition are akin to rules, while recommended, neutrality, and disliked are analogous to norms in a society. Majeed (1990) defines five of these principles as follows:

- Obligation (*waajib*) – One who acts upon this principle is rewarded, but one who leaves it is penalized. Examples of obligatory actions are: prayers, fast during Ramadhan, and Hajj.
- Prohibition (*haaram*) – One who acts upon this principle is penalized, but one who leaves it is rewarded. Examples of prohibited actions are: gambling, cheating, and drinking intoxicants.
- Recommended (*sunnah*) – One who acts upon this principle is rewarded, but one who leaves it is not penalized. Examples of recommended actions are: brushing the teeth and the non-obligatory prayers.
- Neutrality (*mubaah*) – One who acts upon this principle is not rewarded, but one who leaves it is not penalized. Examples of neutral actions are: wearing wool instead of cotton, and eating chickpeas instead of beans.
- Disliked (*makrooh*) – One who acts upon this principle is not penalized, but one who leaves it is rewarded. Examples of disliked actions are: using too much water (wasting) during ablution or bathing.

In some obligatory actions, there exist a set of pre-conditions which must be fulfilled for the actions to be valid and rewarded. A tenet (*rukn*) is a set of pre-conditions that determines whether an obligatory action is valid or invalid. For example, fasting in the month of Ramadhan is obligatory (and will be rewarded) only if you are a Muslim. Being a Muslim is a pre-condition for this obligation (a tenet). Valid and invalid principles determine whether an action is either right or wrong for every obligation and these two principles depend on the tenet that comes together with any obligation. Majeed (1990) defines these two principles as follows:

- Valid (*sah*) – a state in which actions are acceptable based on a set of imposed conditions. For example, the performance of a prayer is valid if it is performed with all its correct steps, utterances and body movements.
- Invalid (*batal*) – a state in which actions are not acceptable due to violation of a set of imposed conditions. For example, in the act of praying, the *rukoo'* (i.e. bending the body forward with hands on the knees) and the *sujood* (the prostration) are principal acts of the prayer. If the *rukoo'* and the *sujood* are not performed, the prayer is invalid.
-

A definition for rules and norms is exemplified in Figure 1 for an obligation of performing prayers. Given such obligation, the normative influences of the recommended, neutrality, and disliked states are clearly indicated in the figure, whereby a person who is obligated to pray knows at which point in time that he/she is rewarded or penalized when he/she performs the prayer. The figure also shows the prohibition state which one should avoid. The limits between these states are for illustration only and do not explicitly represent any absolute values. It is in fact, differs greatly across obligations, for example in fasting or hajj.

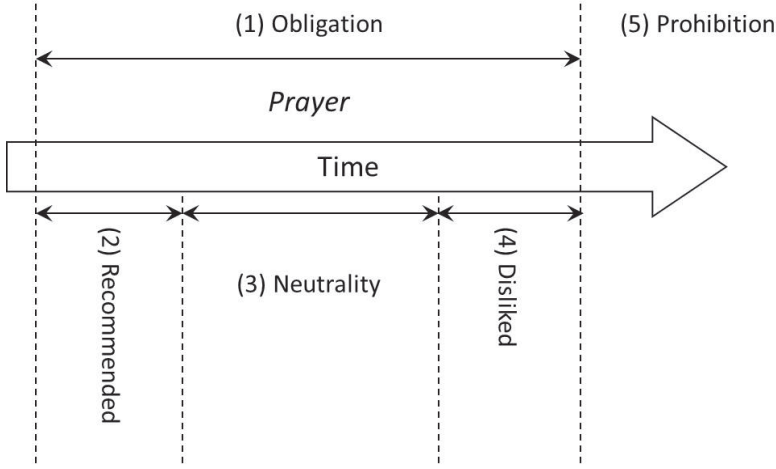



Figure 1: Modeling the Principles in Islamic Jurisprudence for Prayers

Table 2 further deliberates on the principles of obligations, prohibitions, recommended, neutrality, and disliked together with a judgment of valid or invalid based on a group of tenets specific in prayers as partially adapted from Majeed (1990).

Table 2: Details of the Principles in Prayer

| **Tenets for Prayer** |
|---|
| Conditions that make prayers obligatory upon a person:<br>• He/She must be a Muslim.<br>• He/She has attained the baligh status.<br>• He/She is sane.<br>• She is not in the hadath akbar state, that is, she is free from menstruation and nifaas.<br>• He/She sees and/or hears. Prayer is not obligatory upon a person who was born deaf and blind or a child who became deaf and blind. |

Conditions of the fardh prayers:

- He/She must be a Muslim.
- He/She has already attained the mumayyiz status.
- The prayer-time has already been announced.
- He/She know of the tenet (*rukn*) acts of the prayer.
- He/She does not believe or think that a rukn (principles) act is a recommended act.
- He/She is in a pure state.
- His/Her person, clothes and the place upon which he is praying are free from impurities (*najis*).
- His/Her Islamically coverable parts are covered.
- He/She faces the direction of Kaabah (the *qiblah*).

The tenet (*rukn*) acts of prayer:

- To state the intention.
- To say 'takbeeratul ih-raam' – 'Allaahu akbar' at the commencement of the prayer.

| **Obligation** | **Prohibition** | **Recommended** | **Neutrality** | **Disliked** |
|---|---|---|---|---|
| Prayers are obligatory on every individual Muslim who is sane and who has attained puberty | - Perform prayer after the Asr prayers until sunset.<br>- Perform prayer after the Subh prayers until sunrise.<br>- Perform prayer when the sun rises until it is seen with the naked eye to be about seven feet high. By that time it would be about 7.45 to 8.00 a.m. in the morning in this region. | - To recite the qunoot during the Suboh prayer.<br>- To stand for the reciting of the qunoot.<br>- To say the aameen after reciting the faatihah. | Do all obligatory actions (tenet) | - To turn the face from facing the qiblah except when performing the salaam.<br>- To lean against something – a wall, table, etc. |

| | | | | |
|---|---|---|---|---|
| | - Perform the prayer when just before sunset when the sky line is golden in color.<br>- Perform the prayer when the sun is directly overhead – the shadow cannot be seen. | | | |
| **Valid** | | | **Invalid** | |
| Follow all tenets | | | Violate at least one tenet | |

## FORMULATING THE OP-RND NORMATIVE AGENT FRAMEWORK

We assimilate the concepts in the Islamic Jurisprudence to govern the actions of agents in a normative framework while maintaining the underlying semantics. Based on the concepts and semantics of the principles introduced in Section 3, we consider Obligation and Prohibition (OP) as rules imposed by a legislator in a normative environment. We propose three principles: Recommended, Neutrality, and Disliked (RND) as norms for our multi-agent system. Consequently, we call our framework as the OP-RND Framework. The definitions in this framework are based on an intelligent agent *a*, which is the agent on which the rules and norms pervades.

**Definition 1:** A rule, r, is a mutually exclusive state of obligation, O and prohibition, P imposed on an agent, where,

- ❑ obligation is a state in which the agent must perform an action and is rewarded for doing it but penalized otherwise,
- ❑ prohibition is a state in which the agent must avoid an action and is rewarded for leaving it but penalized otherwise.

**Definition 2:** A norm, n, is a mutually exclusive state of recommended, R, neutrality, N and disliked, D, where,

- ❑ recommended is a state in which the agent is rewarded for performing an action but is not penalized otherwise,

- neutrality is a state in which the agent is neither rewarded nor penalized for performing or avoiding an action,
- disliked is a state in which the agent is rewarded for avoiding an action but is not penalized otherwise.

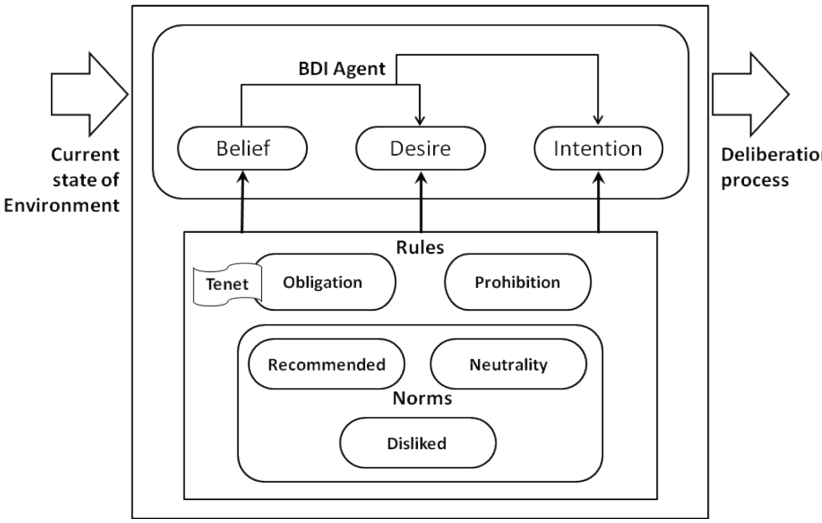
**Definition 3:** A tenet, t, is a set of preconditions imposed on obligations to determine the validity of an agent's action.

Our contention in adopting these principles for a normative agent framework is two-fold. Firstly, some of these principles (obligation and prohibition) show striking similarities to the concepts proposed by other normative frameworks, i.e., (Lopez, 2004). Secondly, the three selected principles (recommended, neutrality, and disliked) are semantically appropriate for our logical model of norms, in the sense that they do not exhibit the strength of rules and they have clear concepts of reward and penalty associated with them (Lopez, 2004; Majeed, 1990).

In any agent actions, there are bound to be obligations, which the agent must fulfill and prohibitions, which the agent must avoid. For each obligation, a tenet determines whether an action is valid or invalid. We model these as rules attributed by the OP components of our framework. On the other hand, we contend that norms should exhibit weak rules or soft constraints in the environment while the agents are attempting to achieve a goal. We model these as norms attributed by the RND components of our framework.

In the RND component, we propose the Recommended principle to influence an agent in performing an action and gets rewarded for doing it, but not penalized for leaving it. In the principle of Neutrality, the agent is not rewarded or penalized if it follows or violates an action. In the third principle, Disliked, an agent is rewarded if it leaves an action, but is not penalized for doing it. However, we assert that if the agent is in the disliked state for too many times, the disliked state will gradually become prohibited. Figure 2 shows the OP-RND Framework based on these principles.

**Figure 2:**
The OP-RND Framework




For every obligation, the tenet determines whether an action is valid or invalid. Obligation and prohibition make up the rules, while recommended, neutrality, and disliked constitute the norms, which are influenced by the rules within the environment. The outcome on the interaction within this environment influences the beliefs, desires, and intentions of a BDI agent. We believe that agents should be motivated to perform their tasks if they are aware of each state of the environment and the rewards or penalties they could get if they fulfill or violate the norms.

## Case Study

To formalize the logical model in the OP-RND framework based on the principles of Islamic Jurisprudence, we select the process of examination paper preparation and moderation process (EPMP) to model submission of documents as the study. In one instance, a Lecturer is obligated to prepare and submit a complete examination paper set within four weeks to a Moderator who reviews the paper. Within the duration, there are other tasks that the Lecturer needs to do together with the paper preparation and submission.

In this instance, the paper submission to the Moderator is the normative goal, which needs to be fulfilled in the normative environment. The other goals, which we called personal goals, are based on the need of each individual Lecturer, such as taking leave, attending workshops or courses, attending meeting, and so forth. Both the normative and personal goals need to be prioritized during the four weeks duration based on the RND

framework. Figure 3 models the proposed principles in the EPMP domain. Table 3 further deliberates on the principles of obligation, prohibition, recommended, neutrality, and disliked together with a judgment of valid or invalid based on a group of tenet in the submission of a document.

The next section provides a definition for each of the principles exemplified in Figure 3 for an action of submitting a document within a stipulated time.

**Figure 3:**
Modeling the Principles in Islamic Jurisprudence for Submission of Document

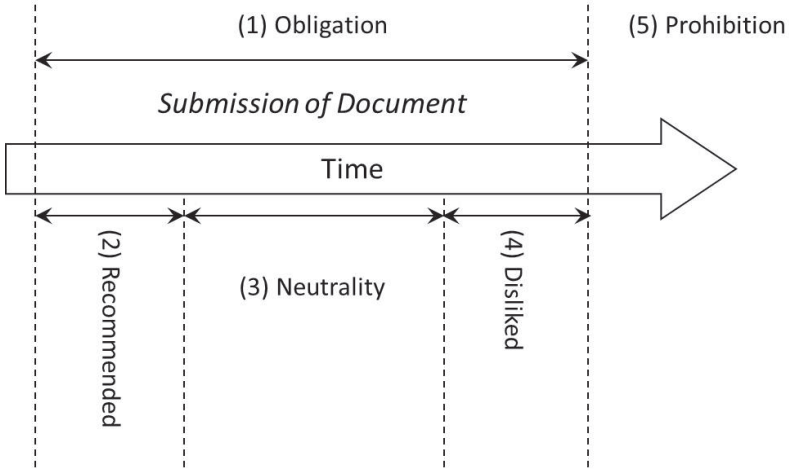



**Table 3:**
Details of the Principles in Submission of Document

| **Tenets for Submission of a Document** |
|---|
| Conditions that make documents obliged upon a person:<br>• Must be a staff<br>• Responsible to the submission of document<br>Conditions of the document:<br>• Must be PDF version<br>• Formatted to document requirements<br>The tenet (*rukn*) acts of submission:<br>• Within the duration from Week 10 to Week 14 |

| Obligation | Prohibition | Recommended | Neutrality | Disliked |
|---|---|---|---|---|
| Submission of document on Week 10, due Week 14 and must be submitted in PDF form. | Submit after Week 14 | Submit on or before the fifth day of Week 10 | Submit after the fifth day of Week 10 until the last two days of Week 14 | Submit on the last two days of Week 14 |

| Valid | Invalid |
|---|---|
| Submit between Week 10 and Week 14 in PDF format | Submit after Week 14 and/or not in PDF format |

**The Logical Models**

In formalizing the logical models for the EPMP domain, we introduce five attribution variables that are used in the formalisms. These are:

1. Comply, which refers to an agent's action towards the norms and rules by which the agent decides to follow.
2. Violate, which refers to the agent's action towards the norms and rules against which the agent decide to reject.
3. Reward, which refers to a merit point given by a legislator agent to the agent.
4. Penalty, which refers to a demerit point given by a legislator agent to the agent.
5. Tenet, which refers to the conditions relating to the rules given by the legislator agent to the agent.

There are five definitions for the normative OP-RND framework based on the five attribution variables above. In the following definitions, we define a principle $X$ in the form of $X_{an}(x, p|c)$ in which an agent $a$, who is responsible to agent $n$ must see to it that $x$ is in context $c$ or, is otherwise penalized with $p$. Agent $a$ is the normative agent and agent $n$ is the agent who issues and monitors the norms. $V(x, a)$ is defined as the violation of $x$ by agent $a$. We define the logical model of the five principles below with respective example for each definition that corresponds to Figure 3.

**Definition 4**: Obligation, $O$ is redefined as $O_{an}(x, p|Y)$ where agent $a$ is obligated to agent $n$ to see to it that $x$ is in context $Y$, otherwise it is penalized with $p$, if and only if:

- $Y \rightarrow x$: If $Y$ then agent $n$ desires and has a goal $x$, and this goal has been distributed to agent $a$.
- $Y \vee \{\neg x\} \rightarrow V(x, a)$: if $Y$ and $\neg x$, then agent $n$ has the goal and the desire $V(x, a)$; to recognize it as a violation by agent $a$.
- $Y \vee V(x, a) \rightarrow p$: if $Y$ and agent $n$ decides $V(x, a)$, then agent $n$ desires and has a goal that penalizes agent $a$.
- $Y \rightarrow \neg p(n)$: if $Y$, then agent $n$ desires not to penalize. This desire of $n$ expresses that it only penalizes in case of violation.
- $Y \rightarrow \neg p(a)$: if $Y$ then agent $a$ desires $\neg p$, which expresses that it does not like to be penalized.

**Example 1:** There is a Lecturer agent $L$, who needs to submit a document at time $t$ (i.e., Week 10), does not like to be penalized, and submits it on time and the document should is in PDF format. Each of the examples shown below corresponds to the model above.

a. *Submit_document*$\rightarrow$ {*submit, t*}
b. *Submit_document*$\rightarrow$ {$\neg$*submit*, *t*}
c. {*Submit_document*, (*submit*, *a*)} $\rightarrow$ *r*
d. {*Submit_document*, *V*(*submit*, *a*)} $\rightarrow \neg p$
e. {*Submit_document,* PDF}$\rightarrow$ valid
f. {*Submit_document,* $\neg$PDF} $\rightarrow$ invalid

**Definition 5**: Prohibition, $P$ is redefined as $P_{an}(x, p|Y)$ where agent $a$ is prohibited by agent $n$ to see to it that $x$ is in context $Y$, otherwise it is penalized with $p$, if and only if:

- $Y \rightarrow x$: if $Y$ then agent $n$ desires and has a goal $x$, and this goal has been distributed to agent $a$.
- $Y \vee \{\neg x\} \rightarrow V(x, a)$: if $Y$ and $\neg x$, then agent $n$ has the goal and the desire $V(x, a)$; to recognize it as a violation by agent $a$.
- $Y \vee V(x, a) \rightarrow p$: if $Y$ and agent $n$ decides $V(x, a)$, then agent $n$ desires and has a goal that penalizes agent $a$.
- $Y \rightarrow \neg p(n)$: if $Y$, then agent $n$ desires not to penalize. This desire of $n$ expresses that it only penalizes in case of violation.
- $Y \rightarrow \neg p(a)$: if $Y$ then agent $a$ desires $\neg p$, which expresses that it does

not like to be penalized.

**Example 2:** There is a Lecturer agent $L$, who needs to submit a document at time $t$ (i.e., Week 10), given a deadline in Week 14, does not like to be penalized, but submits it after the deadline in Week 15 but the document is in PDF format. Each of the examples shown below corresponds to the model above.

a. $Submit\_document \rightarrow \{submit, t\}$
b. $Submit\_document \rightarrow \{\neg submit, t\}$
c. $\{Submit\_document, (submit, a)\} \rightarrow r$
d. $\{Submit\_document, V(submit, a)\} \rightarrow \neg p$
e. $\{Submit\_document,$ PDF$\} \rightarrow$ valid
f. $\{Submit_document, \neg$PDF$\} \rightarrow$ invalid

**Definition 6**: Recommended, $R$ is defined as $R_{an}(x, p|Y)$ where agent $a$ is recommended by agent $n$ to see to it that $x$ is in context $Y$, otherwise it is penalized with $p$, if and only if:

- $Y \rightarrow x$: If $Y$ then agent $n$ desires and has a goal $x$, and this goal has been distributed to agent $a$.
- $Y \vee \{\neg x\} \rightarrow V(x, a)$: if $Y$ and $\neg x$, then agent $n$ has the goal and the desire $V(x, a)$; to recognize it as a non-violation by agent $a$.
- $Y \vee V(x, a) \rightarrow r$: if $Y$ and agent $n$ decides $V(x, a)$, then agent $n$ desires and has a goal that rewards agent $a$.
- $Y \vee V(x, a) \rightarrow \neg p$: if $Y$ and agent $n$ decides $V(x, a)$, then agent $n$ desires and has a goal that does not penalize agent $a$.
- $Y \rightarrow \neg p(n)$: if $Y$, then agent $n$ desires not to penalize. This desire of normative system expresses that it only penalizes in case of violation.
- $Y \rightarrow \neg p(a)$: if $Y$ then agent a desires $\neg p$, which expresses that it does not like to be penalized.

**Example 3**: There is an agent $L$, who needs to submit a document at time $t$ (i.e., Week 10), does not like to be penalized, and submits it at an earlier week, such as Week 8. Each of the examples shown below corresponds to the model above:

a. $Submit\_document \rightarrow \{submit, t\}$
b. $Submit\_document \rightarrow \{\neg submit, t\}$
c. $\{Submit\_document, (submit, a)\} \rightarrow r$

d. $\{Submit\_document, V(submit, a)\} \rightarrow \neg p$

e. $\{Submit\_document, n\} \rightarrow \neg p$

f. $\{Submit\_document, a\} \rightarrow \neg p$

In this example, agent $L$ is the agent $a$ who needs to follow the norms and agent $n$ monitors the norms. Based on Figure 3, submission of document at an earlier time is recommended (line (c)) and will be rewarded by agent $a$. It is not a violation if agent $a$ does not perform the submission (line (b) and (d)) and will not be penalized.

**Definition 7**: Neutrality, $N$ is defined as $N_{an}(x, p|Y)$ where agent $a$ is neutral by agent $n$ to see to it that $x$ is in context $Y$, otherwise it is penalized with $p$, if and only if:

- $Y \rightarrow x$: If $Y$ then agent $n$ desires and has a goal $x$, and this goal has been distributed to agent $a$.
- $Y \vee \{\neg x\} \rightarrow V(x, a)$: if $Y$ and $\neg x$, then agent $n$ has the goal and the desire $V(x, a)$; to recognize it as a non-violation by agent $a$.
- $Y \vee V(x, a) \rightarrow \neg r, \neg p$: if $Y$ and agent $n$ decides $V(x, a)$, then agent $n$ desires and has a goal that are not rewarded or penalized agent $a$.
- $Y \vee V(x, a) \rightarrow \neg r, \neg p$: if $Y$ and agent $n$ decides $V(x, a)$, then agent $n$ desires and has a goal that is not rewarded or penalized on agent $a$.
- $Y \rightarrow \neg p(n)$: if $Y$, then agent $n$ desires not to penalize. This desire of $n$ expresses that it only penalizes in case of violation.
- $Y \rightarrow \neg p(a)$: if $Y$, then agent $a$ desires $\neg p$, which expresses that it does not like to be penalized.

**Example 4:** There is an agent $L$, who needs to submit a document at time $t$ (i.e., Week 10), does not like to be penalized, and submits the document on Week 10.

- $Submit\_document \rightarrow \{submit, t\}$
- $Submit\_document \rightarrow \{\neg submit, t\}$
- $\{Submit\_document\ (submit, a, t)\} \rightarrow \neg p, \neg r$
- $\{Submit\_documentV(submit, a, t)\} \rightarrow \neg p, \neg r$
- $\{Submit\_document, n\} \rightarrow \neg p$
- $\{Submit\_document, a\} \rightarrow \neg p$

Referring to Figure 3, submission of document on time is neutral (line (c)) and is not rewarded or penalized if agent $a$ complies or violates the rule (line (c) and (d)).

**Definition 8:** Disliked, $D$ is defined as $D_{an}(x, p|Y)$ where agent $a$ is disliked by agent $n$ to see to it that $x$ is in context $Y$, otherwise it is penalized with $p$, if and only if:

- $Y \rightarrow x$: If $Y$ then agent $n$ desires and has a goal $x$, and this goal has been distributed to agent $a$.
- $Y \vee \{\neg x\} \rightarrow V(x, a)$: if $Y$ and $\neg x$, then agent $n$ has the goal and the desire $V(x, a)$; to recognize it as a non-violation by agent $a$.
- $Y \vee V(x, a) \rightarrow r$: if $Y$ and agent $n$ decides $V(x, a)$, then agent $n$ desires and has a goal that rewards agent $a$.
- $Y \rightarrow \neg p(n)$: if $Y$, then agent $n$ desires not to penalize. This desire of $n$ expresses that it only penalizes in case of violation.
- $Y \rightarrow \neg p(a)$: if $Y$ then agent $a$ desires $\neg p$, which expresses that it does not like to be penalized.
- If $N$ represents the number of times agent $a$ complete the task in disliked state and $N>3$; $Y \vee V(x, a, N)$: if $Y$ and agent $n$ decides $V(x, a, N)$, then it is recognized as a violation by agent $a$.
- $Y \vee V(x, a, N) \rightarrow p$: if $Y$ and agent $n$ decides $V(x, a, N)$, then agent $n$ desires and has a goal that penalized agent $a$.

**Example 5:** There is an agent $L$, who needs to submit a document at time $t$ (i.e., Week 10), does not like to be penalized, but does not submit it until Week 13 (i.e. before the deadline on Week 14).

a. $Submit\_document \rightarrow \{submit, t\}$
b. $Submit\_document \rightarrow \{\neg submit, t\}$
c. $\{Submit\_document, V(submit, a, t)\} \rightarrow r$
d. $\{Submit\_document, n\} \rightarrow \neg p$
e. $\{Submit\_document, a\} \rightarrow \neg p$
f. $\{Submit\_document, V(submit, a, N)\} \rightarrow violation$
g. $\{Submit\_document, V(submit, a, N)\} \rightarrow p$

In Figure 3, submission of document at a much later time is disliked and is rewarded if agent $a$ violates the rule (line (c)). But if agent $a$ does it many times, it will become a violation by agent $n$.

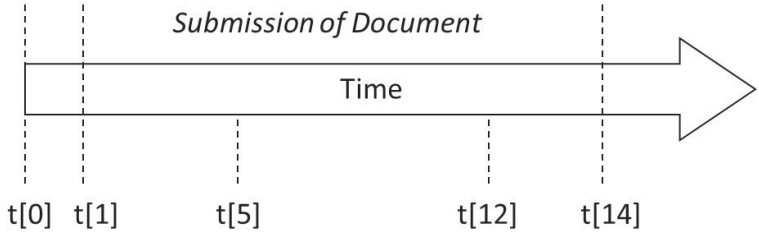
In these five examples, as reflected in Figure 3, we show that agent $a$ is aware of the normative states (i.e. Recommended, Neutrality, Disliked) in the environment. It is valid if the agent submits the document in PDF format but invalid in any other format. The reward and penalty models in each state influence the agent to decide accordingly.

## EXPERIMENTS AND RESULTS

We test and validate the normative framework on the EPMP domain for a period of 14 days in two set of experiments. Both experiments are conducted using the JADE (Java Agent DEvelopment) framework (Caire, 2003). We instantiate 100 agents for each experiment to compare the performance of the agents. The first is a control experiment conducted on a (non-normative) blind agent system in which the agents attempt to achieve the goal blindly without considering other variables in the environment, such as reward and penalty. The second experiment is conducted on our normative framework in which the environment variables and norms are considered. The norms logic in this experiment is developed using the JESS platform, i.e. a Java-based logic language. All agents react accordingly based on this logic.

Figure 4 shows the submission timeline for the EPMP domain. In this figure, t[0] represents the starting time for the examination paper preparation process. Realistically, we fixed the duration of completion to five days so that the agent is able to submit in the Recommended state between t[1] and t[5]. We also impose a constraint such that the agent should not submit the document at t[13] and t[14], to prevent the agents from submitting in the Disliked state. All other slots are acceptable for submission, but are not recommended.

**Figure 4:**
Submission Timeline




We compare the results between the blind and normative agent systems with the same normative goal, while keeping personal goals equal. Figure 5 shows the distribution of submissions (x-axis) against the number of blind agents (y-axis). The figure shows that submissions are mostly made at t[11] and t[12], i.e., late submissions in Neutral state.

**Figure 5:**
Submission Results for Blind Agents

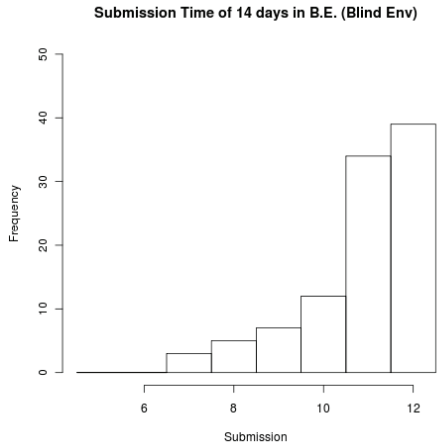
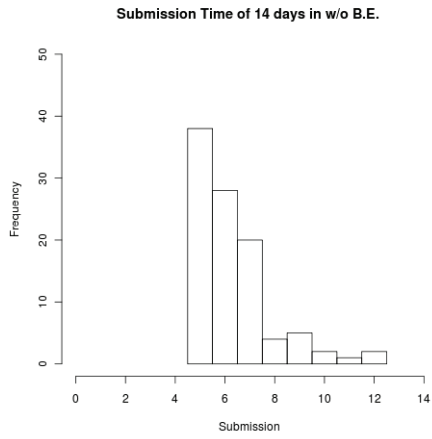



Figure 6 shows the distribution of submissions for the normative system, from which we observe a significant improvement in submissions, which are at t[5] and t[6], i.e., agents submit in the Recommended state or immediately after. The figure also shows that all constraints are satisfied.

Based on the results, we can clearly see that the submissions of normative agents are much earlier than the blind agents. The results show that the rules and norms have indeed produced the desired effect of earlier submissions and improved the agents' performance.

**Figure 6:**
Submission Results for OP-RND Agents



The framework could be implemented in domains which have similar and comparable features. In particular, it is most suitable for domains in which the performance of tasks is imposed with deadlines (i.e. scheduled tasks) and the completion of work is demanded before the deadline expires, such as in project management. The framework also enables the authority to appraise the performance of individuals by evaluating the rewards and penalties attained by them.

## CONCLUSIONS

The Islamic Jurisprudence espouses the principles of obligation (*waajib*), prohibition (*haram*), recommended (*sunnah*), disliked (*makrooh*), and neutrality (*mubaah*) (Majeed, 1990). Meanwhile, the concept of reward and penalty, as established by the *Sharia* are imposed to validate the tenet (*rukn*). Such principles form the underlying foundation to our normative OP-RND framework for multi-agent systems. In the framework, a rational agent exercises its norms within the duration of its obligation and attempt to avoid encroachment into the prohibited area. While the agent is at liberty to violate the norms (i.e. exercising its norms in the Disliked state), the framework's reward/penalty structure motivates the agent to execute its actions in more favorable states, i.e., Recommended or Neutrality. The side effects of these outcomes manifest a significant improvement in agent coordination and subsequently improve the overall performance.

The experimental results have shown that incorporation of rules (i.e., Obligation and Prohibition) and norms (i.e., Recommended, Neutrality, Disliked) in a normative framework greatly influences the agents' performance. Nonetheless, a single agent, similar to human, has to attend to more than one goal, both the normative and its personal goals. These goals could be in conflict with each other and degrade the agents' performance. However, not all personal goals are mandatory because some may be postponed or ignored in order to achieve the normative goal. In our future work, we shall formalize the goals into different types, e.g. normative goal and personal goal. In the case of personal goal, we shall characterize further whether the goals are mandatory, discretionary, or having flexible durations. This is important because an agent should be intelligent enough to prioritize its goals and able to choose which of its personal goals could be postponed or ignored. We shall also look at the diligence factor in agents to see if such factor could be implemented to further improve their performance.

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