

Norm Emergence in Multiagent Systems: A Viewpoint Paper*

JAAMAS Track

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ABSTRACT

The literature on norm emergence and normative MAS considers norms from two perspectives, namely: prescriptive norms using deontic concepts, and emergent norms that capture preference behaviour. We find that both perspectives lend themselves naturally to specific ways of representing norms in a society, as either explicit or implicit. Our analysis of the norm emergence literature, contributes several insights for future research in normative MAS. For example, opportunities for the study of online norm synthesis mechanisms and the investigation of the conversion of social norms, typically observed in norm emergence, to legal norms in normative MAS. Conversely, concepts from normative MAS can be brought into norm emergence research. For example, the study of stable emergence to avoid instability in MAS and the investigation of whether high cognitive ability agents, typically found in normative MAS, can demonstrate norm emergence. We summarise our analysis and outline future challenges and opportunities for cross-over between norm-emergence and normative systems research.

KEYWORDS

norms, norm emergence, normative multiagent system (MAS)

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1 INTRODUCTION

Our analysis of the literature on norm emergence concludes that several concepts in norm emergence are applicable to *normative* MAS research. Morris-Martin et al. [17] consider the prescriptive and emergent norm perspectives and show how concepts from the emergent perspective can be applied to the prescriptive and vice-versa. For example, we posit how implicit norms/behaviours can be encoded and explicitly represented as norms in a normative MAS. The subject for analysis in [17] is the literature that directly addresses norm emergence or presents norm emergence mechanisms, although we do also cite literature indirectly related to norm emergence to contextualise our insights and provide background.

The purpose of this paper is to summarise the eight challenges and opportunities in the study of normative MAS and of norm

emergence that came out of our survey, namely: (i) how to design MAS for norm emergence (§2.1), (ii) further investigation of characteristics of simulation models of emergence (§2.2), (iii) online norm synthesis (§2.3), (iv) high cognitive agents demonstrating norm emergence (§2.4), (v) frameworks to support norm emergence (§2.5), (vi) stable emergence (§2.6), (vii) prescription of both social and legal norms (§2.7), and (viii) conversion of social norms to legal norms (§2.8), each of which is discussed at greater length in [17].

2 FUTURE CHALLENGES & OPPORTUNITIES

2.1 MAS design for norm emergence

Several characteristics of simulation models of emergence identified in [17] have been shown to support the emergence of norms in MAS, for example observation capabilities, learning methods (pairwise or collective) and norm propagation mechanisms.

Other identified characteristics can, depending on their use, have either a negative or positive influence on norm emergence. Examples are social topology and reinforcement learning. The categorisation of an agent’s cognitive abilities did not indicate any effect on norm emergence, although the high-cognitive ability agents were not investigated. The compatibility of these various characteristics with respect to norm emergence is not straightforward and needs further study. In the design of MAS whose goal is to support norm emergence, the characteristics we have identified may constitute a checklist for designers, from which they can choose to incorporate and prioritise those characteristics that support the context and goal of the target domain. A typical example is the use of enforcement or punishment as a propagation mechanism, which must have adequate observation mechanisms to ensure the observation of violations, to enable their subsequent enforcement. Additionally, if a centralised or distributed approach is used for enforcement, then global or local observation capabilities, respectively, are necessary.

2.2 Characteristics of models of emergence

We identify some characteristics of simulation models whose impact on emergence has not been extensively studied, namely: (1) the type of games played when modelling agent interaction in a game theoretic manner; and (2) the type of exploration used by learning agents to learn new norms. In general, we observe that the success of existing norm emergence mechanisms does not work for all social topologies, where agent observability is limited to immediate neighbours or private knowledge. This does not however hold if the observability horizon is extended to include neighbours of neighbours [9, 10], where it shows that norm emergence is possible irrespective of the underlying topology. The majority of literature cited in [17] concludes that social topology plays a significant role in

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norm emergence, results from [9, 10] suggest this can be overcome with enhanced observability. Existing mechanisms should therefore aim to replicate these results across all well known social topologies.

2.3 Online Norm Synthesis

Norm synthesis mechanisms are usually aimed at assisting MAS designers in determining the appropriate set of norms before the system goes live, i.e. offline. More recently, work has investigated online norm synthesis where the majority of approaches utilise a centralised mechanism [1, 13–16], while to the best of our knowledge, only [4] takes a distributed approach. A system with a fixed set of norms will typically lose relevance over time in dynamic and complex environments, consequently, we identify a need for the exploration of a range of mechanisms for both centralised and decentralised online norm synthesis, under the constraints of potentially limited or localised knowledge.

2.4 Emergence in high-cognitive ability agents

We observe a gap in the literature with respect to whether agents with high-cognitive abilities can demonstrate norm emergence using their action selection strategies. What currently prevails in the emergence literature is that agents use relatively simplistic methods for deciding which action to choose from a set of potential actions, but there is nothing in norm emergence that demands the action selection strategy be simplistic. Consequently there is no *prima facie* reason why a (subset of a) population of high-cognitive ability agents could not converge to the same preferred action in similar situations, utilising non-simplistic reasoning and decision selection methods.

2.5 Frameworks to support norm emergence

Most research reports on the investigation of one or two characteristics and show how these can promote norm emergence, but no study to date has considered whether a single generic or adaptive framework can be applied to MAS to facilitate norm emergence, irrespective of the type and properties of the MAS. Is it possible to combine the supporting characteristics of norm emergence as identified in Morris-Martin et al. [17] into a single optimal mechanism? Or would an adaptive mechanism which utilises a fixed set of characteristics for a given type or configuration of MAS be able to support norm emergence in MAS? Recent studies [10, 12] describe mechanisms that have been successful across several MAS characteristics, suggesting that a generic or adaptive strategy may be a viable direction for research.

2.6 Stable Emergence

The emergence of a norm in the literature usually focuses on the realisation of that norm emergence, but does not consider the stability of the norm that emerges. Therefore, if the stability of the normative MAS depends upon the stability of its norms, it would necessitate the inclusion of mechanisms to avoid oscillatory emergent norms, as in Savarimuthu et al. [18].

2.7 Prescribing social and legal norms

Prescribing both social and legal norms in a MAS has been put forward previously by Conte and Castelfranchi [5], and except

for Frantz et al. [6], there has been no implementation of the concept. We observe that MAS typically either operate with explicitly-defined legal norms or implicitly-defined social norms, and if both are present, only the legal norm is explicitly defined.

Human societies however are typically governed by both social and legal norms and in some situations, the existence of social norms helps ensure legal norm adherence [21]. Over time, MAS have successfully adopted human behaviour in modelling agent societies and the prescription of both social and legal norms could be beneficial in working towards the achievement of transparent agent behaviour. Explicit representations of both social and legal norms will also enable agents to reason about both in the same way and encourage a better understanding of norm emergence in such societies.

2.8 Converting social norms to legal norms

The norm life cycle as expressed by Andrighetto et al. [2] contains a norm evolution phase, where norms become codified into law, evolve or decay. Similarly, there is a shared perspective in the literature [3, 19, 20], though not further investigated, that norms can become laws.

We believe there is an opportunity for research where an emergent norm(s) within a MAS can potentially become an obligatory action for a given situation. A similar concept is demonstrated in Ghorbani et al. [7, 8], where the popular strategy proposed by agents within the society becomes the strategy to be followed by all the agents. The viability of the concept is also examined by Haynes et al. [11], who propose that beneficial emergent behaviours in a system be encouraged and spread, while others be discouraged through a three-stage process of engineering of emergent norms: (i) identification or detection of the possible emergent norm, (ii) evaluation of the benefit of the possible norm to individual agents or the system as a whole, and (iii) encouraging or discouraging the spread of the norm.

3 CONCLUSIONS

This paper discusses some challenges and opportunities in the study of norm emergence and normative MAS. An extended and fully referenced discussion appears in Morris-Martin et al. [17]. Here we highlight the areas that we believe offer the most potential for future (MAS) research in Sections 2.1–2.8. Taken together, the above form the basis for a roadmap for the investigation of norm emergence in normative MAS, comprising high-cognitive ability agents, where conventions can become laws, through formal decision-making institutional structures. Critical questions here include: can high-cognitive ability agents synthesise the appropriate norms for the normative system, is local knowledge sufficient to synthesise norms, can the legal norms arise from the behaviour of the participating agents, and how do we ensure stability in self-regulating normative MAS?

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