Who's friends, who's boss?
Affiliation and hierarchy in agent societies

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Abstract. The everyday life of people working in organizations requires continuous coordination. In fact, coordination is what organizations are for. Yet people do not stick to what the organization prescribes for them to do. Human coordination is rife with issues of group affiliation, power, and leadership, and associated emotions. The fields of organizational behaviour and management reflect this. Modellers of organizational behaviour need to take these areas on board. This goes beyond formal organization. While sophisticated logics are used as well as intricate models of organizations, the social, volitional nature of the humans in them is hardly modelled, thus limiting the practical usability of these models. The article reviews the literature on group affiliation and hierarchy in agent-based models. It gives pointers as to which developments seem promising for advancing MAS and social simulation. It discusses the potential of complementary roles in agent-based models for formal organisation and human social nature. The MAIA meta-model for social simulation [7] serves as an example.

Keywords. Coordination, hierarchy, volition, agent-based models, multi-agent systems, literature review.

1 Introduction

Many agent-based models (ABM), virtual humans and robots have the aim to support coordinated tasks in human organizations. To date, the social, volitional side that is crucial to any human endeavour is not fully taken on board by these models. This was recently argued by Kaminka [1], who pleads for curing robot autism, which he mainly defines in the physical world, and by Dignum et al. [2] who call for agents that are social at their core; they use the term 'social landscape' to denote this. The agents live in a social landscape defined by ties of group affiliation and hierarchical relations. In a keynote, Gilbert [3] explains why coordination is so difficult to model. He defines it as 'the state of working together' and states that coordination can be based

on cooperation or competition. Implicitly he raises two central questions of social life: who's friends – with whom will I cooperate, and who's boss – who decides. This article is about these two questions known by many names. We shall use the terms group affiliation and hierarchy. They have been central to the study of human social behaviour in organizations, ranging from theoretical to consultancy-oriented. The common denominator in this work is that people are social creatures driven by volition. Groups, relationships, and hierarchy are always prime determinants of how people behave, along with context- and task-specific matters. This makes sense. In an evolutionary as well as an ontogenetic sense, we are social primates – children, parents, friends, citizens - before being members of formal organizations. Affiliation and hierarchy are crucial to humans, as they are to other social animals, whatever they do. Theoretical frameworks in social science explicitly mention an affiliation-related and a hierarchy-related dimension of social life [4-6]. Yet little of this has transpired to multi-agent systems (MAS) to date.

This article tries to make a general statement that could apply to a wide range of ABM and MAS. "ABM" for agent-based systems and "MAS" for multi-agent systems are two research fields that overlap. ABM tends to model large numbers of simple agents and their emergent dynamics whereas MAS tends to model smaller numbers of agents with quite a bit of internal cognitive complexity. Here we use both terms as near-synonyms, under the idea that the field may converge if they have the common mission of modelling coordination. Hence the "agent societies" in the title.

This wide ambition bears the risk of vagueness. Just so as to give the argument some focus, let us take as an example a state-of-the art system that is much more socially aware than most. The MAIA [7] framework is a meta-model for building ABM or MAS based on Ostrom's Institutional Analysis and Development framework. The framework provides modelling concepts to capture a large range of social phenomena. The MAIA architecture is built from five "structures": collective (actors that stand for people or organizations), constitutional ("the social context"), physical, operational (dynamics), evaluative (outcomes). MAIA conceptualizes agents as having properties (e.g. risk propensity), personal values (e.g. corruption), belongings, information, and intrinsic behaviours (e.g. requiring energy). Agents make decisions about the tasks they perform and every decision requires a criterion. The case used as an instance is that of a boss's willingness to hire children instead of adults in the recycle industry in India. The criterion hinges on the risk-taking variable and on a binary corruption variable. The constitutional structure states that every actor takes a role in the society, and that every actor has a specific objective specified to that role. A role is defined as an abstract representation of a set of activities that are performed according to some rules in order to reach social objectives (e.g. increase of income). The objective is defined as the expected result of a role.

While this is an impressively rich description, it only addresses the two social dimensions of affiliation and hierarchy inasmuch as they are formally specified in roles. In reality, formal organizations never fully match informal social ties; the social fabric around the organization will be all-important. MAIA agents have no family relations, for instance. This makes it hard to model aspects of the real-world situation that are crucial to those they concern. As an example, suppose a boss hires the children of his

relatives to work for him. The MAIA model instance calls this corruption, yet it could be perceived as a moral duty to assist relatives by a real boss, depending on the nature of affiliation and hierarchy in that society. If the society has poor standard of living, poor institutions but strong family loyalties, and if people are willing to subjugate their destinies to the will of parents and rulers, then the law is unlikely to carry any power. Actual power will depend on informal hierarchy in the local context, for instance, related to caste or class. A local ruler may be perceived as more moral if he provides child labour opportunities than if he does not.

So the "social context" of MAIA's constitutional structure is, for the moment, limited to formal roles, rules and dependencies. Incidentally, the article's authors are the first to point out that many areas for improvement remain.

How could such a social structure for MAIA, or for any other model, look? There is a wealth of studies in agent-based systems that address coordination. In this paper we review this literature, aiming for breadth rather than detail, to see how it can help the MAS / ABM community. Some of the literature might not be applicable to the MAIA case, but could be applicable to readers' studies.

2 Coordination in agent-based models

A vast corpus of agent-based literature has been written about coordination in humans and other animals. An extensive set of references, for which there is no space in the article, can be obtained from the authors. In the following we have selected some references for more detailed discussion because we deem them particularly interesting for the MAS and social simulation community.

It may be useful to point out that we think of the areas of affiliation and hierarchy as more general than some of the topics that have been the subject of streams of research in agent-based work, such as coalition formation or opinion dynamics. Such areas are special cases, and the agents in the models on these issues may or may not be motivated by group dynamics and hierarchy. This is no value judgement; it can actually be quite valuable to use ABM for checking whether group patterns can emerge without any pre-existing group-based or hierarchical motivation on the part of the agents; see e.g. the overview by Squazzoni et al. [8]. However, consciousness of group identity and hierarchy matter to people, and are basic tenets of social science. Our interest here is in the generic nature of group affiliation and hierarchy for any task of coordination that may be set to agents. How can these generic tendencies be modelled in tractable ways? Note that for coordination to occur, typically a variety of people and roles are needed; the step from affiliation and hierarchy to coordination is by no means self-evident.

2.1 Group affiliation

People and other animals organize themselves in groups, ranging from societies to communities, clans, clubs, and families. In interaction they negotiate who belongs to the group and who does not. These groups in turn define one's identity and self-esteem and consequently, behaviour. Group affiliation mechanisms are implemented

at different levels, from world regions to small groups, from abstract to specific. Group boundaries are therefore defined by varying concepts and theories. Table 1 summarizes the literature.

The simplest form of affiliation does not even deal with group affiliation, but only with proximity. It is a form of distributed cognition that is often called swarms or crowds. Agents perceive a limited set of neighbours and are influenced only by their behaviour. Imitation is the typical response. Quite a bit of work has been done on animals. Here we just mention recent experimental work by Couzin et al [9] that shows how, if a swarm of fish has alternative destinations, the presence of individuals without any preference can have the self-organizing effect of dampening the influence of minorities with a vehement preference for one destination in favour of majorities with a mild preference for the other destination. Thus, by implication, large fractions of uninterested individuals can limit the power of extremists without any symbolic affiliation of hierarchy, but just through self-organisation.

Table 1: Themes in ABM on group affiliation.

Level of detail	**Concepts & Theories**	**Mechanisms**
Swarms	Proximity	Imitation
Social Networks	Contagion; word-of-mouth; opinion leaders; strong and weak ties; Social comparison theory	Imitation; imitation via thresholds or preferences; imitation due to uncertainty
Homophily	Strong and weak ties	Similarity between agents; familiarity
Multiple group identities	Theory of Planned Behaviour (subjective norm); Theory of interpersonal behaviour	Weighted peer judgment; commitment vs membership

The most abstract form of group boundaries applied in ABMs, mainly innovation studies, are *social networks*. This concept posits 'connections' between agents. The group boundary within these models is defined by the number of others the agent is connected to. Some concepts that are based on this social interaction restriction are word-of-mouth; contagion; imitation; strong and weak ties; and opinion leaders. In the case of imitation, mechanisms are often combined with individual (heterogeneous) preferences or thresholds, such as a match with individual preference regarding the action [10-12] or sensitivity to peer pressure [13-15] e.g. due to uncertainty, conceptualized in the Consumat Framework [16].

A more specific group boundary is homophily, which refers to the *similarity between agents* as a restriction rule for socially influenced behaviour. Note that more similar does not necessarily mean more attractive; there could be nonlinear relationships between the two. Some famous evolutionary type ABMs are based on this principle, such as the model by Axelrod on the evolution of culture [17], Schelling on

segregation [18], Sakoda on two-group dynamics [19] and Riolo et al. on cooperation [20]. This principle has been applied in several land use and land cover change models [21-23], where agents decision for a new residential location is partly based on neighbours' similarity with personal characteristics.

Models on opinion dynamics apply the same mechanism, but with more complexity. The first opinion dynamic models used binary, linear opinion models. Here the opinion of an agent is dependent on the weight the agent attaches to the opinion of his opponent. The weights can be static or dynamic, which means they can also depend on time or on the opinion itself. In the static case, the weights are part of the agent's initial profile and determine whether they put a positive or negative weight on another agent's opinion. In this case the weights of an opinion do not change over time.

A variation to this model is an opinion model under social influence. Here the agent adheres to his initial opinion by a certain value g, and is influenced by 1 – g: i.e. agents differ in their susceptibility to other agent's opinions and the weights they put on another agent's opinion. Here, susceptibility to another agent's opinion is given as a personality trait, i.e. it does not depend on the characteristics of the other agent. Lastly, the weight to a certain opinion can also be dependent on time.

In agent-based models of opinion dynamics, agents have continuous opinions which they can adjust due to interaction with other agents and importantly based, adjustments are based on the similarity in opinion between agents. Here, social influence is dependent on the similarity in opinion between agent *i* and *j*. Two models that have pioneered opinion dynamics in the agent-based model's research, and that studied what would happen if the weights of a certain opinion are dependent on the opinion itself, are the models by Hegselmann and Krause [24], and Deffuant et al [25]. They both use opinion averaging through interaction. In the Deffuant-Weisbuch model, the modellers use pairwise interaction for averaging opinions, while in the Hegselmann-Krause model, the modellers use the average of the opinion of all other agents that lie in the agent's area of confidence [26].

The third level of detail is rare in ABM, despite being the rule in real life. These models use group boundaries. A pioneering model is the checkerboard model of social interaction by Sakoda[19]. Sakoda's agents walk around in a square world. They belong to two 'social identities', and per model run they have fixed preferences for members of their own, and the other identity. Depending on the set of preferences they can e.g. merge, separate, keep pursuing one another, or form cross-group dyads.

Several ABMs, especially in innovation diffusion research, apply Ajzen's [27] Theory of Planned Behaviour (TPB) [10, 28]. This theory suggests that a persons' intention towards engaging in behaviour increases when important reference groups (e.g. family, friends, colleagues) are likely to approve the action, also termed the subjective norm. This theory assumes that varying group identities play an important role in behavioural outcomes. Kaufmann et al. [28] indirectly model multiple group identities by using empirical data on the subjective norm. A promising agent framework by Feola and Binder [29], the integrative agent-centred framework (IAC), also indirectly accounts for multiple group identities by allowing for multiple roles with associated norms, and reference groups' opinion. A model that combines two reference groups,

although not explicitly stated, is the model by Valeeva and Verwaart on udder health management improvement [30]. Here, a farmer's behaviour towards adopting an udder health measure is influenced by three different types of information from three different sources: legislation, information campaigns from companies and government, and other farmers.

A full focus on group dynamics is brought into the discussion by Prada and Paiva [31]. Their model includes both membership of groups and relative power. Agents engaged in collaborative tasks with humans, who developed more trust in these agents than in socially naïve agents. Ongoing work explores similar ideas. Degens et al. [32] apply the notion of a "moral circle" as a building block of social structure for agents. Mascarenhas et al. [33] operationalize Kemper's notion of status claims and conferrals as constitutive elements of social interaction. Before agents can make relational claims on others, they have to build appropriate status, called "social importance".

2.2 Hierarchy

Social hierarchy is a ubiquitous feature in humans and animals. Individuals are never identical and resources are scarce. Hierarchy can have a clear advantage in groups. It can help avoid costs for aggression, e.g. when individuals have to compete for resources. It can also help in more peaceful situations, when cooperative individuals decide on collective behaviour. Social hierarchy is also involved in determining relationships between group members [34].

Hierarchy may emerge of itself. Ohnishi [35] simulated the evolution of hierarchically structured groups by letting agents interact asymmetrically and exchanging "power" consisting of material and/or information. The study showed that distribution of power causes a hierarchical structure that will evolve into groups with one or more leaders.

The *steepness* of hierarchy can be important for the social structure, as shown by various studies. Nandi et al. [36] investigated two eu-social species of wasp. Decreased aggressive (dominance) behaviour of the queen increased complexity in the social organisation by change of worker strategies and physiological change (development of a pheromone signal). DomWorld, a well-known ABM in biology [37, 38], simulates grouping and competition by dominance interactions in primates. In DomWorld, larger differences in dominance values of individuals cause more despotic primate societies, and smaller differences correspond to a more egalitarian society, with a different spatial behaviour and gender role distribution. The models have been validated against macaque societies of various species.

Many other animal models have focussed on the emergence of coordination through self-organization. Conradt and Roper [39] modelled despotism and democracy as mechanisms for group decision-making. In most cases, democracy had the lowest group activity synchronisation (fitness) costs. In a review on decision making mechanisms in animals, the importance of differentiating combined from consensus decisions was emphasized [40]. A combined decision entails that individuals decide individually but their choice will depend on what others do, leading to self-organization of the group. If an individual can only communicate locally (e.g. as in

mob or shoals of fish) consensus cannot be reached and self-organisation will ensue [40]. A consensus decision is made in agreement with all group members.

2.3 Affiliation and hierarchy

Agent-based architectures quite naturally allow emergent dynamics between affiliation and hierarchy. For instance, in social networks the number of ties refers to the centrality of an individual within the network. Opinion leaders have relatively many connections and therefore more influence [15, 16]. In simulations with a spatial element, agents that have a preference for others [19] or that are dominant over others [41] may end up in the centre.

Dávid-Barrett et al. [34] included multi-level networks by making a differentiation between optimal personal network size and optimal group size. They investigated, under the assumption that individuals want to cooperate, whether the structure of interactions affected the choices of the agents to synchronize their behaviour with their group members. Interaction limitations by social, spatial or time constraints played a key role. An interesting result of this model was that individuals of steeper social hierarchical communities needed fewer relationships.

Primate models also combine affiliation, hierarchy and resulting self-organization. King et al. [42] showed that coordination in groups of baboons can be explained by simple rules of self-organization. In their ABM they showed the importance of the network structure and the relationships between individuals, as individuals are more likely to copy and follow the behaviour of their 'closest friends'. The dominance of animals was also included in this study. Rands et al. [43] found that the agent with the lowest energetic status often emerged as a temporarily leader for synchronized foraging behaviour. Still, being the highest in rank increases the chance of a successful initiation of behaviour and being followed by other individuals [44].

3 Discussion

People are born into a social world, with informal ties of affiliation – "Whom do I belong to?" - and hierarchy – "Whom do I defer to?". ABM show how these ties lead to self-organization of social life. Among humans, formal institutions are being created to improve upon informal affiliation and hierarchy: to regulate who are colleagues, and who are superiors. Therefore, MAS that model formal organizations with concepts such as roles, rules, and norms are obviously useful. Our point is that modelling this formal side cannot be an alternative for modelling the informal social world. Instead it is a superstructure on top of the informal social world. From informal sources we learned that some MAS researchers explicitly disagree with this view, arguing that a single formalism is enough to describe social relations. We respond by saying that such an attitude limits the potential power of MAS to represent human coordination issues.

Of course not every MAS requires the full range of human sociality. On the contrary: some models convincingly show that social order can emerge without pre-existing

affiliation of hierarchy. Depending on the case, more is needed. This should be an explicit design-time decision.

The relationship between the various aspects of affiliation and hierarchy reviewed here with our 'social landscape' is also far from simple. For instance, opinions might or might not be a proxy for deeper-seated group affiliation. People could use opinions as group affiliation emblems. There are creativity techniques for groups consisting in hiding the identity of contributors precisely because people could otherwise make their opinions depend on what their friends said.

3.1 Social structure in the MAIA architecture

How does this work out for our example?

Let us take the example of a boss who may or may not hire child labour. It is against the will of the European clients to do so, but it may be in his own interest, and it may be perceived as socially desirable in his village.

MAIA agents live in a world with formal affiliation and hierarchy. Our boss has relative power to other members of the organized world, such as the European client, and the workers. He (most likely a 'he' in the Indian context, but it could be a 'she') has no formal power over anyone who has not been hired.

In the current version, the yes/no variable of corruption will decide about the boss's motive for hiring a child, together with a personality variable of risk propensity. Family, caste, friendship and mutual obligation are not modelled. MAIA's constitutional structure could perhaps be enhanced to express such relational roles and dependencies; but that might undermine its current clarity or over-stretch its data model. In line with [2], a realistic meta-model would need to include relational logic at its core, upon which the formal organisational model with its roles and rules would be grafted. So perhaps besides the five structures of MAIA, a social structure could be created that only dealt with intrinsically social aspects. This would then span the social landscape in which the agents live. MAIA agents could then also be parents, children, or caste members, and have all the unwritten rules that come with these social roles, independent of the constitutional structure. Their actions could, in the social structure, be evaluated purely for their relational impact. The dynamics of running the model would then cause a mutual interdependence between the various structures, including the social structure.

If we create a social structure for this boss, that structure would possibly include

- A reference group of villagers, including a commitment of the boss to that group, and a hierarchical position in that group, and a measure of the importance of hierarchy – probably related to cultural "power distance" in the sense of [45].
- A reference group of European clients, also with a commitment of the boss to it. Since this is not really a group but rather a category we might not be able to give it a power distance.
- A reference group of the boss himself, representing self-interest.

The social landscape thus formed can allow the simulation to compute the social contributions of the boss's motivation to hire a child, the expected status gain or pen-

alty from hiring the child. The formula could use: the sum of (his commitment to each reference group * that reference group's power * that reference group's pressure).

To determine whether the boss will actually hire a child, the social structure could be combined with factors that MAIA already models: personality characteristics of the boss, and that boss's formal authority about hiring. Note that there would need to be a mechanism for determining the relative salience of the informal and formal world.

As a "use case", the outcome of adding a social structure could be that one boss stops hiring children after a personal visit from a European client, not for formal reasons, but because the client visit honoured him so much that it increased his commitment to the reference group of European clients, which gave more weight to their rules.

The literature reviewed here can help designers think about the architecture of the social structure. In this paper we shall not attempt to design it, but just put forward suggested directions for development. In the case of MAIA, adopting for instance a social network, we could think of the boss making more social comparisons to the extent that he is uncertain, that is, looking at what other bosses in the recycle industry are doing. The decision by other bosses to hire children or not, can be a reason for the boss to follow this behaviour. If we also have hierarchy in our social structure we can let the other persons' influence depend on whether he looks up to them (for example because they have more or better connections, are senior family, or because their companies are bigger). The hierarchical structure of the society may also be important for individual decision making. In a more despotic society, the boss will probably decide on this issue himself, or be forced from above. If the structure is more egalitarian, the decision could be democratic. If in addition to all of this, we adopt reference groups, then the influence of the visit by the EU client can also be placed in the balance.

The point is not whether these ideas would be the best to adopt for MAIA, for after implementing and testing with local people they would no doubt turn out to be flawed; but to show that an intrinsically social landscape for agents can increase their usefulness. MAIA is just one case of the general argument here: meta-models of formal organizational structures can be populated with agents that are intrinsically social and cultural, and this combination is needed for progress.

3.1 Further research

The literature review, though far from complete, indicates that although models on group affiliation exist for both humans and animals, there is hardly any work on hierarchy or dominance among humans. It is quite possible that power is too much a taboo among humans. Few people are willing to admit to dominance or submission motives in themselves, although they do impute them to others. The issue will not be solved by ignoring it though. Robots and virtual agents are beginning to permeate people's lives. The biggest obstacle today is their lack of sociality [2]. Insights from

the ABM literature reviewed here can help remedy this situation. The task ahead is still vast though, and decades of work will be needed.

Our literature survey shows a very modest contribution of social science that leaves room for a lot of experimentation. The typical focus on mechanism in ABM leads to an easier connection with biology than with psychology or sociology. The focus on logic in MAS seems at variance with the preoccupations of social scientists.

One issue apparent from the literature review is that self-organization, studied with very convincing results in many species of animals, has not been much used to study the emergence of patterns in human societies. This seems a really promising area of study.

The suggestion to have both an informal social world and a formal, institutional one in a simulation begs a question. How would the system decide how to weight informal social logic against formal organizational rule? Actually, a lot can be gleaned about this from cross-cultural studies that could be incorporated. Culture consists of the answers that a society has found to the coordination tasks it faces in order to divide social resources and avoid infighting. Dimensions of culture [45] that have emerged time and again in studies that compare values between societies revolve around issues of affiliation (individualism – collectivism) and hierarchy (masculinity, power distance). They can be used in ABM for comparing coordination issues across countries.

Many ABMs show that self-organization is an important force. This also offers research opportunities: how can an agent world self-organize while subject to formal norms and rules? How could changes in the informal social world affect the fate of formal organizations? How can the socio-cultural world co-evolve with the formal institutional world?

Another untouched issue is how the physical world impinges upon the social world, for instance through selective perception. Here, Kaminka's [1] ideas can serve.

Finally, a re-examination of social science for useful theory that might have been left unused by the ABM research is a major endeavour left untouched in this article. A recent example of this is [46]. In that paper, the agents are intrinsically social but live in an undifferentiated world; adding formal institutions and / or physical structure to their world, or perhaps rather adding this social world to existing other models, would be a valuable next step.

4 Conclusions

This paper argued 1) that group affiliation and hierarchy are two core issues of coordination among humans; 2) that current MAS work pays little attention to their real-world complexity; 3) that there are ample sources of inspiration in the ABM literature; 4) that social scientific theory has been little used in that literature.

A finding from the literature is that dominance has been understudied in ABM of humans. ABM about animal societies, with ideas useful for modelling humans, make up for that. Numerous other concepts of affiliation and hierarchy are mentioned, ranging from none – where it is self-organization that leads to coordination – to generical-

ly social, to specialized in a single area such as opinion dynamics. The authors hope to inspire researchers in social simulation and MAS to re-use these ideas, so that they will fill their clever designs with social agents. We are just getting started.

Furthermore, the article posits that it could be fruitful to provide social agents with both a formal structure of group belonging and hierarchy, such as an organization structure, and an informal one that is constituted by their nature as social and cultural beings but not encoded in formal roles. The former provides the stick to beat the dog with, whereas the latter provides the reason. As a result, the same formal structure populated by different people will yield different results.

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