More formally, the framework is modified in the following way. Each norm is extended with the *authority power* $P \in \mathbb{R}, -1 \leq P \leq 1$:

Definition 10. *A norm ω is a tuple $< \upsilon, p, t_d, t_a, t_e >$, with p being either:*

- *$p = A_\alpha - C_\alpha$, when the norm is imposed by the agent α (the situation when $\upsilon = X^{\alpha:\rho}_{\alpha':\rho'}\varphi \circ \Gamma$, X being either O, P or F),*
- *$p = c$, where c is some constant set during inserting the norm into the global normative state, $-1 \leq c \leq 1$, otherwise (the situation when $\upsilon = X_{\alpha:\rho}\varphi \circ \Gamma$, X being either O, P or F).*

Now, when a norm is inconsistent, in order to resolve the conflict, a particular agent a checks if his power $p_a = A_a - C_a$ is big enough to pursue its own goal or to comply with the will of the group (i.e. to break the prohibition or to respect it, respectively):

Definition 11. *The agent α with power $p_\alpha = A_\alpha - C_\alpha$ facing inconsistent norms ω, ω', without loss of generality assuming $\omega =< \upsilon, p, t_d, t_a, t_e >$ to be prohibition:*

- *performs the action υ when $p_\alpha > p$,*
- *does not perform the action υ when $p_\alpha \leq p$.*

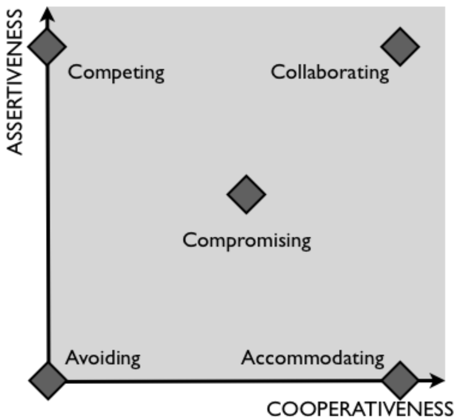

Fig. 5. Thomas and Kilmann's styles of dealing with conflict based on individuals' levels of assertiveness and cooperativeness.

Both parameters, assertiveness and cooperativeness, have an impact on the decision whether a particular agent will comply with the norm or not. The approach is inspired by social sciences. which indicate that people resolve conflicts in similiar manner [19]. Thomas and Kilmann describe five styles of reacting to conflict situations based on individuals' assertiveness and cooperativeness levels: competition, collaboration, compromise, accommodation and avoidance, as presented in Fig. 5. In our previous work we adopted this classification and created five strategies for conflict resolution in multiagent settings: *Competitive*, *Collaborative*, *Compromising*, *Accommodating* and *Avoiding* [20]. Our study indicated that the strategies possess many differences concerning different aspects: some of them are more risky, other are safer, they are suitable to adopt in distinct circumstances, their usage should depend on what an agent actually wants to achieve. In this way, differentiating agentsŹ behaviour can be useful in situations, where agents are not homogenous either physically (e.g. they do not have the same sensors) or concerning their roles (e.g. their goals are different). In such situations it is better not to search for *optimal* strategies, but for *maximizing* ones. In noncooperative game theory maximal players try to exploit perceived weaknesses in their opponentŹs way of playing [21]. Maximizing strategy in our approach standed for a plan that best corresponds with current goals of a given agent (which may be completely different from goals of agents of different types) and the current state of a population, i.e. the number of conflicts and proportions of agents representing different strategies. In our work we answered questions about existence of a dominant strategy and came to the conclusion that there is no strategy that will win in all circumstances. We also answered the questions about influence of proportions of agents of various types and influence of number of conflicts in a population on the performance of distinct startegies. The best circumstances for each strategy, in which it can be adopted, were investigated.

4.3 Social influence

Introduction of assertiveness and cooperativeness levels gives agents means to resolve conflicts, but still a way to coordinate their actions by choosing proper conflict resolution strategies is needed. In order to achieve that, we introduce a mechanism allowing for influencing those levels and in effect affecting also the choice of strategies. The mechanism is based on the model of social influence described in our previous work [22]. In sociophysics literature there exists a multitude of social influence models, but they possess some drawbacks which make them inappropriate to apply in our case. They can be classified into discrete (including binary) models and continuous models depending on the representation of opinions that are being influenced.

Typical discrete models include Ising model [23], Sznajd model [24], social impact model [25], voter model [26], etc. These representations of social influence, sometimes called the *toy models*, are useful for simplifying opinion dynamics explanations, like e.g. using the temperature notion to introduce the stochastic behaviour [23] or proposing *United we Stand, Divided we Fall* rule to implement the phenomenon of social validation [24] etc. However in our case, the drawback of these models is their discrete nature, as our measurments of assertiveness and cooperativeness levels have continous characteristic.

This fact brings our attention to the continuous models, that mainly include Hegelsmann-Krause model [27], Deffuant-Weisbuch model [28] and their numerous variants and extensions [29–32]. These approaches, however, also possess some limitations. Some of them assume bounded confidence of agents, which means that the agent adjusts its opinion only towards the opinions that are not very distinct (that lay in the ϵ-interval around the agent's opinion) [28, 31, 32]. As we want to influence various levels of assertiveness and cooperativeness, this approach is not suited for our case (for instance an agent with high value of cooperativeness may affect an agent with low value of cooperativeness). Other drawback is that some of the models assume influence dynamics, that leads to a consensus [31, 27, 29]. Consensus is not a preferred state in our approach, as it would mean a single fixed strategy of conflict resolution.

This is why we proposed our own model of social influence, which is similar to Hegelsmann-Krause model, but also introduces some major differences [22]. The model assumes that each agent a possess its level of influence $\phi_a \in [0,1]$ and impressionability $\delta_a \in [0,1]$. The details of incoporating the model into the conflict resolution framework and the details of the model itself will be described in the next subsection. The approach was evaluated on the problem of social mood dimensions influences on each other [22]. Social mood, the aggregated mood of a society, emerges from complex system of individual moods and their interactions. The real social networks consist of millions or even billions nodes constantly influencing each other. Such a complex system was modeled by a simple MAS. It was achieved by aggregating moods of individuals into a small number of so called *mood dimensions*. Profile of Mood States, known and well-vetted psychometric instrument, distinguishes seven mood dimensions (Tension, Happiness, Calmness, Vigor, Fatigue, Confusion and Friendliness) [33]. If we apply them to a society at large, i.e. to social mood, it is possible to measure influences of one mood dimension on another. We assessed the social mood by means of analyzing a volume of 20,110,489 tweets containing words: "feel" or "feeling" posted during 14 days from July 7th to July 20th, 2014. In order to obtain a mood score of a tweet and classify it as a representant of one of mood dimensions, we compared each word from a tweet against each word from a lexicon of so called *emotional* words. Then we proposed a framework which can approximate or even, in some circumstances, be predictive of future social mood states. The framework consists of a model of social influence, which we also utilize in this work, and an evolutionary algorithm learning proper network topology and model parameters. The experiments showed that small networks can indeed approximate social mood with reasonable mean absolute percentage errors ranging from 9.19% to 10.69%. These results could be further improved using longer computations. Thus, the work proposed quite complete framework of assessing and analyzing social mood based on the real-world data.

4.4 Incorporating the model of social influence into the framework

The social influence model is incorporated into the framework in the following way:

1. $Agents = \{a_1, a_2, ..., a_n\}$ is the set of agents.
2. Each agent a possesses its level of:

  - assertiveness $A_a \in [0,1]$,
  - cooperativeness $C_a \in [0,1]$.
3. Each agent a possesses its level of:
  - influence $\phi_a \in [0,1]$, which denotes how much it is affecting others,
  - impressionability $\delta_a \in [0,1]$, which denotes how much it is being affected by others.
4. The resolution of a conflict by an agent a leads to the update of its assertiveness and cooperativeness levels:
  - $A_a := A_a(+/-)\phi_a\delta_a A_a$,
  - $C_a := C_a(+/-)\phi_a\delta_a C_a$.

  The choice of a sign (+/-) depends on the decision (to respect or to neglect the prohibition) and on the type of conflict resolution strategy (*Competitive*, *Collaborative*, *Accommodating* or *Avoiding*). It will be described in detail in the next subsection.
5. The update of levels of assertiveness and cooperativeness of agent a leads to update of corresponding levels of all agents being in the scope of influence of this agent. For each such agent a':
  - $A_{a'} := A_{a'}(+/-)\phi_a\delta_{a'} A_{a'}$,
  - $C_{a'} := C_{a'}(+/-)\phi_a\delta_{a'} C_{a'}$.

  Where the choice of a sign (+/-) is the same as the choice of the agent a. Meaning that if, for example, the level of assertiveness of the agent a rose (+ sign), so will the level of assertiveness of the agent a'.
6. If the update of assertiveness or cooperativeness level assigns the value that is out of range, i.e. $A \notin [0,1]$ or $C \notin [0,1]$, we change its value to the nearest viable value, i.e. to 1 or to 0.

4.5 Typology of conflict resolution strategies, update mechanisms for social attitudes and underlying dynamics

When an agent faces a conflict, it needs to decide whether it should respect the prohibition or pursue its obligation/permission. Its decision affects its levels of assertiveness and cooperativeness (as described in S. 4.4, P. 3). What still remains to be described is the choice of signs (+/-) in the equations. It depends on two factors:

- what is the conflict resolution strategy of the agent,
- wheter it will respect or neglect the prohibition.

The conflict resolution strategy of a given agent a depends on its levels of assertiveness and cooperativeness:

$$\begin{cases} \text{Competitive}, & when\ A_a \geq 0.5 \land C_a < 0.5 \\ \text{Collaborative}, & when\ A_a \geq 0.5 \land C_a \geq 0.5 \\ \text{Accommodating}, & when\ A_a < 0.5 \land C_a \geq 0.5 \\ \text{Avoiding}, & when\ A_a < 0.5 \land C_a < 0.5 \end{cases} \tag{6}$$

Knowing the strategy of an agent we can describe the behaviour of its assertiveness and cooperativeness levels changes. Let's remember that during the conflict between obligation/permission (O, P) and prohibition (F):

- assertiveness is connected with performing and action, as the agent wants to achieve its own goals (is obliged/permitted to take an action),
- cooperativeness is connected with not performing an action, as the agent wants to adjust to the will of the group (which prohibited the action).

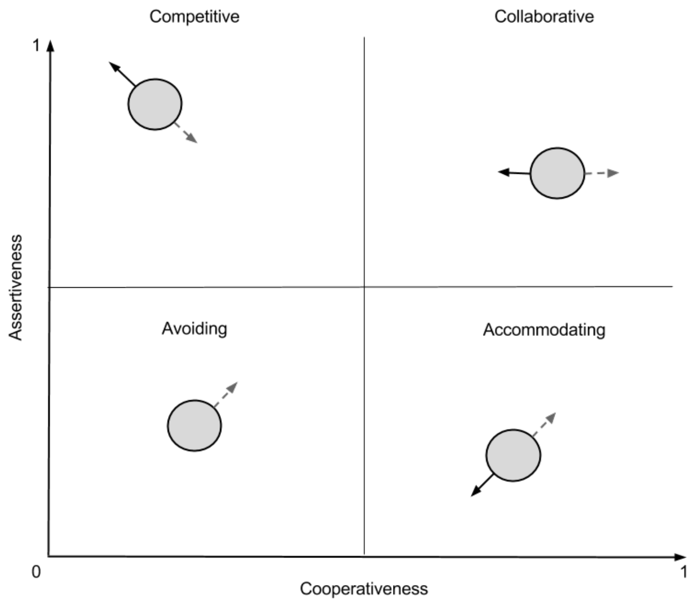

Fig. 6. Changes in assertiveness and cooperativeness levels based on the agent's strategy and type of decision: to break (black arrow) or to obey (grey, dotted arrow) the prohibition.

The agent a facing inconsistent norms ω, ω', without loss of generality assuming $\omega =< \upsilon, p, t_d, t_a, t_e >$ to be prohibition and ω' to be obligation/permission:

1. Representing *Competitive* strategy, if it performs the action υ:
   - its assertiveness A_a increases (sign +),
   - its cooperativeness C_a decreases (sign -),

   as the agent makes the decision that is in line with its own goals.
   If it does not perfom the action υ:
   - its assertiveness A_a decreases (sign -),
   - its cooperativeness C_a increases (sign +),

   as the agent makes the decision that is in line with the goals of the group.
2. Representing *Collaborative* strategy, we can say that the agent "has no ego". If it performs the action υ:

   - its assertiveness A_a stays at the same level (the assignment is of the form $A_a := A_a$),
   - its cooperativeness C_a decreases (sign -),

   as the *Collaborative* strategy most importantly wants to cooperate with the group, it does not perceive breaking the prohibition as an assertive decision (the way the *Competitive* agent would do). Thus the assertiveness level preserves its value. The cooperativeness level of course decreases.
   If it does not perfom the action υ:
   - its assertiveness A_a stays at the same level (the assignment is of the form $A_a := A_a$),
   - its cooperativeness C_a increases (sign +),

   as the agent makes the decision that is in line with the goals of the group, the cooperativeness level increases. Again, the decision has no impact on assertiveness level, as the priority of this strategy is to cooperate.
3. Representing *Accommodating* strategy, the agent constitutes a reverse version of a *Competitive* agent, perceiving cooperation as a better alternative for itself. If it performs the action υ:
   - its assertiveness A_a decreases (sign -),
   - its cooperativeness C_a decreases (sign -),

   as the agent makes the decision that is not in line with the goals of the group and is not what the agent would prefer to do.
   If it does not perfom the action υ:
   - its assertiveness A_a increases (sign +),
   - its cooperativeness C_a increases (sign +),

   as the agent makes the decision that is in line with the goals of the group and its own beliefs.
4. Representing *Avoiding* strategy, the agent always avoids conflicts and cooperates at all times. It never performs the action υ and then:
   - its assertiveness A_a increases (sign +),
   - its cooperativeness C_a increases (sign +),

   as the agent makes the decision that is in line with the goals of the group and its own beliefs.

The dynamics of changes of assertiveness and cooperativeness levels can be visualized and better understood using Fig. 6.

5 A formal representation of the scenario

In this section we revisit the scenario described informally in Sect. 2 and represent it with a view to explore our conflict resolution mechanisms. The set of norms in our scenario consists of the following ones:

1. For every agent α we forbid other agents to enter its scope:

$$< F_{A:R}^{\alpha:r_\alpha} deploy(S,X,Y) \circ \{x_{min}^{\alpha} \leq X \leq x_{max}^{\alpha}, y_{min}^{\alpha} \leq Y \leq y_{max}^{\alpha}\}, P_\alpha, 1, 1, +\infty >$$

where $deploy(S, X, Y)$ denotes deploying the sensor S in the area (X, Y) bounded by the conditions $x^{\alpha}_{min} \leq X \leq x^{\alpha}_{max}$, $y^{\alpha}_{min} \leq Y \leq y^{\alpha}_{max}$, where x^{α}_{min}, x^{α}_{max}, y^{α}_{min} and y^{α}_{max} are specific for each agent α. P_{α} denotes the power of the agent α. Last three parameters denote that the norm is active during the whole MAS run.

2. At the same time we permit the group of agents equipped with better set of sensors to enter other agents' scopes if necessary:

   $$< O_{A:r_{superior}} deploy(s_{superior}, X, Y), p, 1, 1, +\infty >$$

   where $r_{superior}$ denotes the group of agents equipped with better set of sensors and $s_{superior}$ is the said set of sensors.

Now, let the group of agents with normal set of sensors be representatives of $Collaborative$ strategy, i.e. for each such agent a, let:

- its assertiveness level $A_a = 1$,
- its cooperativeness level $C_a = 0.5$.

Secondly, let the *superior* group of agents be representatives of $Competitve$ strategy, i.e. for each such agent a', let:

- its assertiveness level $A_{a'} = 0.85$,
- cooperativeness level $C_{a'} = 0.4$.

Finally, let the influence parameter $\phi = 0.5$ and the impressionability $\delta = 0.2$ for all agents.

Now, we can see that in normal situation the power of $Collaborative$ agents is higher that the power of *Competitive* (in our case *superior*) agents $P_{col} = A_{col} - C_{col} = 1 - 0.5 = 0.5 > 0.45 = 0.85 - 0.4 = A_{com} - C_{com} = P_{com}$. Therefore, facing the conflict of norms, *superior* agent α will not break the prohibition of entering the other agent's scope (let's say it's agent β). It should be in line with our imperative of the system flexibility: finding the balance between maximizing the total observation range and being able to spot "special" events. If the power of the *Collaborative* agent was high enough, probably there was no need to enter its scope. Nevertheless, obeying the norm agent α will change its assertiveness and cooperativeness levels (the way it is described in subsection 4.4 and 4.5): $A_{\alpha} := A_{\alpha} - \phi_{\alpha}\delta_{\alpha}A_{\alpha} = 0.85 - 0.5 \cdot 0.2 \cdot 0.85 = 0.765$, $C_{\alpha} := C_{\alpha} + \phi_{\alpha}\delta_{\alpha}C_{\alpha} = 0.4 + 0.5 \cdot 0.2 \cdot 0.4 = 0.44$ and affect agent's β levels as well: $A_{\beta} := 1 - 0.5 \cdot 0.2 \cdot 1 = 0.9$ and $C_{\beta} := 0.5 + 0.5 \cdot 0.2 \cdot 0.5 = 0.55$. Now, one can observe that the power of β $p_{\beta} = 0.9 - 0.55 = 0.35$ decreased. Nonetheless, it is still too much for the power of the agent α, $p_{\alpha} = 0.765 - 0.44 = 0.325$.

However, it might be the case that the area being observed by the agent β is indeed in need of investigation by the *superior* agent. Let's observe that, now, if another *superior* agent α' will want to enter the area, its power $p_{\alpha'} = 0.45 > 0.35 = p_{\beta}$ will allow it to do so and the area will be investigated with the help of the better set of sensors. Breaking the prohibition will affect levels of assertiveness and cooperativeness of agents α' and β: $A_{\alpha'} := 0.85+0.5\cdot0.2\cdot0.85 = 0.935$, $C_{\alpha'} := 0.4 - 0.5 \cdot 0.2 \cdot 0.4 = 0.36$ and $A_{\beta} := 0.9 + 0.5 \cdot 0.2 \cdot 0.9 = 0.99$, $C_{\beta} := 0.55 - 0.5 \cdot 0.2 \cdot 0.55 = 0.495$. The power of the agent β will increase to $p_{\beta} = 0.99 - 0.495 = 0.495$ making entering agent's β scope more difficult for other agents. However, p_{β} will be a little bit smaller than the initial value - this mechanism accounts for "memorizing" the fact that, sometimes, this area might be in need of investigation by a *superior* agent.

One can observe that with such initial setting of parameters, we allow for one prohibition of entering the area and then, after that, for one entrance to the area and so on. Shifting the initial values of parameters can allow for being more cautious, e.g. letting an agent enter the area after k trials. In order to account for finding the best balance between maximizing the total observation range and being able to spot "special" events, one can imagine that system might be, e.g., learning the best initial parameters given particular environment.

6 Dynamics of strategies interactions: properties

The most important notion during conflict resolution is the power of an agent $P = A - C$. One can notice that the higher is the power of an agent, the more control can it have over other agents (more agents must respect prohibitions imposed by the agent). It also possess an incentive to break prohibitions imposed by others, thus to pursue its own obligations/permissions/goals and not necessarily obey the will of the group. Therefore, it is interesting to see what amount of power can each agent possess given its strategy of conflict resolution:

$$\begin{cases} \text{Competitive}, & \textit{then } P \in [0,1] \\ \text{Collaborative}, & \textit{then } P \in [-0.5,0.5] \\ \text{Accommodating}, & \textit{then } P \in [-1,0] \\ \text{Avoiding}, & \textit{then } P \in [-0.5,0.5] \end{cases} \tag{7}$$

One can notice that *Competitive* agents are potentially the most powerful. For instance, they have an ability to impose norms that can be broken only by other *Competitive* agents. They are also potentailly most capable of breaking the rules imposed by others. *Collaborative* and *Avoiding* agents possess the same power potential, so they can impose norms with the same authority. On the other hand, we should remember that *Avoiding* agents never break any prohibition, as they tend to avoid conflicts at all costs. *Accomodating* agents possess the lowest power. For instance, they can never impose any rule to *Competitve* agents, as well as argue with norms imposed by them.

Another thing worth observing are the interactions between strategies during conflict resolution and changes that they cause in levels of assertiveness and cooperativeness (presented in Fig. 6). In our scenario we observed that when *Competitive* agent was resolving conflicts, we obtained such a conflict resolution dynamics that we exactly wanted: when the agent α broke the rule and entered the scope of agent β, agent's β level of assestiveness increased, level of cooperativeness decreased, making it more difficult for other agents to break the norm again. And vice versa, when agent α was not allowed to enter the area, agent's β level of assestiveness decreased, level of cooperativeness increased, making it easier for other agents to enter the area if there would still be a need for that. Nevertheless, different kinds of dynamics are also possible in the framework. *Avoiding* and *Accomodating* strategies, choosing to respect the prohibition, increase both levels of assertiveness and cooperativeness, thus keeping the power at thereabout the same level (because $P = A - C$). The same situation occurs, when *Accomodating* agent decides to neglect the prohibtion, only the levels are both decreasing. *Collaborative* agents have interesting ways of affecting other agents' power levels, because they never affect the level of assertiveness. Nevertheless, the dynamics is the same as *Competitive*'s. If we would like to describe it using mechanistic metaphor, then it is a sort of *negative feedback* on acts of respecting or neglecting the prohibitions. All these properties can be better understood visualising them using Fig. 6.

Conflict resolution can change assertiveness and cooperativeness levels of an agent and in result change its strategy as well. Such a shift can occur as a consequence of two situations:

1. the decision that resolves a conflict is made by an agent and changes its assertiveness and cooperativenes levels,
2. such a decision is made by other agent and then influences the levels of assertiveness and cooperativenes of the agent.

If the shift in the values of these levels is caused by the decision of the agent itself, then:

- *Competitive* agent might evolve into any other strategy,
- *Collaborative* agent might evolve into any other strategy but *Avoiding* and *Accommodating*,
- *Accommodating* agent might evolve into any other strategy but *Competitive*,
- *Avoiding* agent might evolve into any other strategy.

It is interesting to notice that an agent representing *Accommodating* strategy, perceived as the weakest concerning the power, can not become the representative of the strongest strategy as a result of its own decision. Strong and stable agent representing *Collaborative* strategy cannot degrade itself to *Avoiding* or *Accommodating* strategy, as a result of its own decision.

Second situation, when the strategy of an agent might change, is due to the influence of other agent (other agent resolves a conflict and influences its own and nearby agents' levels of assertiveness and cooperativeness). Table 1 presents transitions to other strategies that are not attainable as a result of interaction with a particular strategy. It is interesting to see that the most powerful strategy, *Competitive*, cannot be transformed into the weakest one, *Accommodating*, by representative of any other strategy. It can only be done by other *Competitive* agent. On the other hand, in order to transform *Accommodating* agent into

Table 1. Table presents sets of strategies that are not achievable as a transition from a particular strategy (*Strategy being influenced*) being influenced by another strategy (*Influencing Strategy*). For instance *Collaborative* strategy cannot become *Avoiding* being influenced by *Competitive* strategy.

	Strategies being influenced			
Influencing strategies	Competitive	Collaborative	Accommodating	Avoiding
Competitive	{}	{Avoiding}	{}	{Collaborative}
Collaborative	{Avoiding, Accommo-dating}	{Avoiding, Accommo-dating}	{Competitive, Collaborative}	{Competitive, Collaborative}
Accommo-dating	{Accommo-dating}	{}	{Competitive}	{}
Avoiding	{Avoiding, Accommo-dating}	{Competitive, Avoiding, Accommo-dating}	{Competitive, Avoiding}	{}

Competitive one, one also needs influence of a *Competitive* agent. Another interesting fact is that the transformations that cannot be attained by *Competitive* and *Accommodating* agents (1st and 3rd row) are "opposite". The transformations that are made with the help of *Collaborative* agents are grouped for *Competitive*, *Collaborative* agents and for *Accommodating*, *Avoiding* agents. It is effect of not influencing assertiveness levels by *Collaborative* agents.

All the above properties of the framework offer system designers means to tune the MAS that they are working on towards a particular multiagent environment of their interest in a simple and comprehensive way. Using the capabilities of the framework they can be much more flexible in resolving conflicts than by using fixed policies.

7 Related work and discussion

In this paper we propose rather subtle mechanism of eliminating inconsistencies in norm-governed multiagent systems, based on a 4-valued logical semantics and a set of variables representing the social attitudes of agents. The framework meets initial assumptions and expectations providing the system with adaptability and flexibility. However, the main drawback of our work is its only preliminary validation. Proper justification of the framework would be either by an empirical study or a theoretical proof. Case study described in the paper can only be viewed as an initial proof of concept and we aim at stronger empirical validation of the approach in the future.

Comparing our proposal to the work of Vasconcellos et al. we shall emphasize that our approach to conflict resolution is based on *subjective* point of view, i.e., based on some internal parameters of agents promoting and receiving the norms. The former approach is *objective* in the sense that conflict resolution is based on premises that are external to individual agents, i.e., either chronological precedence or social structure (hierarchy). The other opposition between two frameworks is the *dynamic-fixed* relation that is emphasized thorough the paper.

The attempts to make normative systems conflict-free can be traced back to jurisdiction practices among human societies. Laws do happen to be inconsistent and legal theorists use three classic strategies for resolving deontic conflicts by establishing a precedence relationship between norms: *lex posterior*, *lex superior*, *lex specialis* [34]. Such approaches are also often applied in context of normative multiagent systems [3, 35]. The work of [36] postulates that following fixed behavioral rules can be limiting in performance and efficiency, which is inline with the vision on this issue presented in our paper. Authors utilize learning techniques in order to provide agents with adaptability and flexibility. They propose a framework in which individual group members learn cases to improve their model of other group members and show that simultaneous learning by group members can lead to significant improvement in group performance and efficiency over groups following static behavioral rules. However, their framework focuses only on a particular testbed problem from the distributed AI literature, namely the predator-pray game. The attempt to provide agents with adaptability and flexibility presented in this paper is more general, as it is applicable to all problems that can be expressed as normative systems.

Different approaches include efforts to resolve normative conflicts online [37]. Authors of the paper present a tractable algorithm to be employed distributedly and demonstrate that this algorithm is paramount for the distributed enactment of a *Normative Structure*. Resolving conflicts online is a similar idea to the one presented in this work, only our approach lets agents tolerate conflicts for some time and resolve them *lazily*. Another way to resolve conflicts among agents is through negotiation [38–41]. It may lead to a consensus and better understanding among the group, but it also takes profoundly longer time to resolve a conflict utilizing this approach. Negotiation techniques proposed in the papers span from agents attempting to make claims using tactical rules (such as fairness and commitment), and agents saying what other claims these claims support or attack, through proposals and goal relaxations based on case-based reasoning integrated with the use of multi-attribute utilities to single function agents and negotiations among them.

On the other hand, conflict is not just a phenomenon occurring in MAS. In fact, it is a far more general issue and can be found everywhere, where a social behaviour is present: among humans, animals, insects etc. Therefore, insights from other sciences, e.g. social sciences, can be useful in the context of multiagent systems. This idea has been given some attention [42]. For instance, authors of [43] try to import sociological insights (mainly from the theory of autopoietic social systems and the pragmatist theories of symbolic interaction) into Distributed Artificial Intelligence. The scope of found anologies is impressive. However, their attempt lacks an attempt of translating sociological knowledge to some kind of mathematical or computational formalism, making the considerations only theoretical. In the work of [44] the sociological debate concerning the micro-macro link finds its counterpart in the investigation of internal and external conflicts of agents. Authors present a conflict resolution framework that covers internal and external conflicts, as well as the issues of conflict detection, conflict avoidance and conflict resolution.

The problem considered in our paper, i.e., given a conflict between norms, propose the best policy for the system as a whole that resolves the conflict, is also being dealt with in [45]. In particular, the paper argues that, if an agent must violate a norm then it should determine which norm to violate in such a way that enables it to otherwise maximise its compliance with the remaining set of applicable norms. This concept of maximising compliance and minimising violation or conflict is similar to the notion of preferred extensions from argument theory. Thus, authors map normative structures to argument theory and show how some resulting heuristics may be applied to minimising the amount of normative conflicts.

This paper extends and integrates previous work. A study of conflict resolution strategies based on the levels of assertiveness and cooperatieness (*Competitive*, *Collaborative*, *Accommodating*, *Avoiding* and *Compromising*) was also conducted in [20]. However, experiments evaluating usefulness of this approach were more specific and application dependent. Namely, agents were playing the game of collecting resources and utilizing their strategies during conflicts. The paper describes how an agent with one, fixed strategy will behave in the given circumstances, that is given the number of conflicts in the population and proportions of agents representing different strategies. The attempt to not rely only on fixed strategies was started in [22], with the proposal of the model of social influence, which has continous characteristic, does not assume bounded confidence of agents and does not assume influence dynamics that leads to a consensus. Those were the properties that were needed in a conflict resolution scenario. Finally, the strategies based on the levels of assertiveness and cooperativeness and the model of social influence were combined with known and well-vetted framework of normative conflict resolution in this paper. In the future we aim to describe more scenarios of real-world applications by the means of our approach, in order to explore it even further and to describe its applicability in different environments.

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