Analyzing Social Conflict via Computational Social Simulation: A Review of Approaches

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Abstract. Social conflict entails a variety of social phenomena, including international conflict, civil war, genocide, organized violence, insurgencies and rebellions, terrorism, riots, etc. Given the heterogeneity of social phenomena encompassed by this notion, it is not surprising that a variety of methodological and theoretical approaches have been applied to study it, ranging from formal game theoretic models to the hermeneutics of narratives. Social conflict has also been studied by means of complex systems research methods, such as agent-based social simulation. We conduct a review of the main formal-theoretical approaches to social conflict including agent-based modeling. We promote the usage of agent-based social simulation for it affords shedding light onto the nature of generative processes related to social conflict. We discuss the implications of such an approach to the study of social conflict against orthodox research designs and point toward its advantages which may facilitate development of more adequate conflict prevention and conflict management procedures.

Keywords. Agent-based models, complexity, computational social science, formal models, social conflict, social simulation

Introduction

How can a computational social simulation approach contribute to the study of complex societal dynamics, and social conflicts in particular? The European Social Simulation Association (ESSA) was founded in 2003 with the objective to promote the development of social simulation research, education and application in Europe [1]. Its Special Interest Group on Social Conflict and Social Simulation (SIG-SCSS) was formed in 2008. It aims at promoting and strengthening the field of social simulation in the domain of conflict research, and to provide an organizational platform for researchers who work on social conflict and social simulation to share, discuss and disseminate their work [2]. We take the opportunity of the SIG-SCSS's foundation to assess the potential of the social simulation method for the analysis of contemporary

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security challenges. A particular emphasis lies on security threats arising from violent social conflicts.

There are many, sometimes contradicting definitions of what a complex system is. Most complexity scientists would, however, agree with the fact that complex systems are of a decentralized and non-linear nature and that many processes that occur within them can be characterized through the notion of emergence. Emergence does not only relate to a condition in which agent state, behavior and interaction combine to generate macro-level outcomes that could not be predicted from knowledge of the agent state, behavior and interaction alone, and result in sporadic volatile episodes the timing, magnitude, duration and outcomes of which are themselves unpredictable [3]; it also refers to the idea that agent state, behavior and interaction depends on and are shaped by macro-level outcomes [4]. The combination of emergence (micro-macro link) and social causation (macro-micro link) is one of agent-based social simulation's virtues in the study of complexity. Such a generative understanding of social science can be fruitfully couched in the Weberian notion of *verstehen* and the idea of dynamics. The purpose of the article is therefore to evaluate the scope of comprehension of social conflicts that can be achieved by the particular method of simulation. In Weber's terms *verstehen* is not only approximated by composing a chaotic and overwhelmingly complex amount of empirical data into an ideal type characterizing particularly relevant aspects of the object under investigation – a technique related to any kind of modeling. But *verstehen* goes further in that an object of investigation's subjective web of meaning – the contextualization of a social situation – should be dissected. We argue that the complex feedback loop between emergence and social causation sheds light on the hermeneutics of *verstehen*.

We ask: "What is it exactly that we are studying and in what way(s) are we able to understand social conflict?" Seeking unification where there "naturally" is no unity is useless. It should be nevertheless an aim to identify particularities that distinguish social conflict from other forms of conflict, such as intra-personal conflicts. Consequentially, we provide a clarification of the concept of social conflict.

A further aim of this meta-analysis is to investigate what we have learned with regard to social conflict from the application of computational social simulation. Our efforts have been guided by the desire to "comprehend" social conflicts using social simulation methods. By means of the "comprehensive approach" we hope to widen our perspective without generalizing "too much too soon". Ideally, we aim to encourage generalization while at the same time guarding a certain amount of context sensitivity in order not to lose base with both the specialist/idiographic and the gradualist critique of the generalist approach [5].

Finally, it is only but fair to mention that we will not be able to do just to anyone who has contributed to the field. What we provide is a limited view of what we tentatively agree should necessarily be included in a computational social simulation approach of social conflict.

1. Social Conflict: Its Meaning, Its Scope

In its broadest sense the term social conflict refers to inter-individual and/or inter-group conflicts. In its common meaning the term excludes conflicts within individual minds, i.e. intra-individual conflicts [6, p. 8]. When used with regard to security considerations, social conflict refers particularly to violent or potentially violent

conflicts among larger collectives such as ethnic groups, nations, states, terrorist groups and organizations, and others.

There are many definitions of social conflict, but the two elements common to most of them are *differences* and *interaction* between parties. Varying levels of importance ascribed to interaction and/or differences are reflected by two broad groups of definitions of social conflict. They mainly differ from each other in their emphasis of action on the one hand and motivation on the other. In other words, their focus either lies on manifest and behavioral or on latent and psychological patterns [5].

Mack and Snyder [7] provide an example of a narrower behavioral definition of social conflict. They conceptualize the idea of a type of interaction relationship between parties who have mutually exclusive or incompatible values. Mack and Snyder list a set of manifest properties characterizing such "interaction relationship". Dahrendorf, by contrast, defines conflict more widely, as "all relations between sets of individuals that involve an incompatible difference of objective". He stresses making use of the term "conflict" not only for "manifest clashes between social forces", but also for contests, competitions, disputes, and tensions [8, p. 135]. Fink gives an even wider definition, ascribing to social conflict "any social situation or process in which two or more social entities are linked by at least one form of antagonistic psychological relation or at least one form of antagonistic interaction" [5, p. 456].

Fink also notes that, apart from the action/motivation dimension, definitions of social conflict differ in many more dimensions, such as: regulated vs. unregulated, indirect (parallel striving) vs. direct (mutual interference), unconscious vs. conscious, impersonal vs. personal, continuous vs. intermittent, communication absent vs. communication present, high communication vs. low communication, peaceful vs. violent, large admixture of cooperation vs. relatively pure antagonism, object-centered vs. opponent-centered, third party controls goal vs. opponent controls goal, based on scarcity vs. based on incompatibility/inconsistency, economic goals vs. non-economic goals, and non-disruptive vs. disruptive [5, p. 454].

It is interesting to compare the two broad groups of definitions of social conflict mentioned afore in terms of their relation to the notion of securitization, conceptualized as social construction of threats to security with reference to collectivity [9, 10, 11]. Social conflict, as conceptualized by narrower definitions, refers primarily to securitizations that have already been accomplished. Manifest behavioral conflict patterns generally indicate the presence of "emergency measures", which have been taken as consequences of securitizations. As noted by Buzan and Wæver: "If people are killing each other in organised ways, or spending large and/or escalating sums on armaments, or being driven from their homes in large numbers, or resorting to unilateral actions contrary in major ways to international undertakings, then it is virtually certain that successful securitisations have taken place" [12, p. 73].

The notion of social conflict as assumed by wider definitions refers not only to securitizations that have already taken place, but also to the possibilities of yet unaccomplished securitizing moves. The emphasis on latent, psychological conflictual patterns points to the high potential for social construction of threats, possibly leading to full-fledged securitizations.

2. Approaches to Social Conflict

According to a perspective from which one may view social conflict, Schellenberg distinguishes between an academic and a practitioners' approach to social conflict [6, p.11]. Academic approaches further vary by scientific discipline. Traditionally, social conflict has been a subject of interest of peace and conflict studies, sociology, political science, history, psychology, anthropology, economy, and mathematics, among others. Practitioners' approaches vary by profession of a practitioner, which may belong to any of the fields including politics, diplomacy, law, defense and security, social work, clinical psychology, labor management, conflict resolution, negotiation, and so on.

Most of contemporary research projects combine several research and professional approaches. The "added values" of such an interdisciplinary approach often include the:
- Widening of horizons and opening new perspectives;
- Comparison of different approaches;
- Ability to address terminological inconsistencies and settling differences;
- Synthesis of various mono-disciplinary findings.

All these may contribute to improved conflict prevention and/or regulation capabilities.

A distinction between the generalist and the specialist approach is related to the mono- vs. inter-disciplinary debate as most of the interdisciplinary approaches aim at generalizations, however limited these may be. Specialists have, on the other hand, tended to raise two main objections to generalist approaches: an idiographic, and a gradualist objection [5, pp. 413-416]. The idiographic objection points to the inherent uniqueness of conflicts. In a more extreme version idiographically oriented specialists tend to view each instance of conflict as special, warranting unique attention and the "true knowledge of particulars" [13]. In practice, however, most of the specialists allow for limited generalizations, which begs the question of where the limits to admissible generalizations should be, with generalists arguing for extending the limits to an ever widening scope. The gradualist objection generally warns against generalizing "too much too soon" and often argues for a consolidating role of middle range theories [14, 15]. Many of the "limited generalists", including the authors of this paper, would find gradualist objection sustained for the most part, and would be willing to submit their generalist findings to gradualist scrutiny.

2.1 Social Conflict by Structural Levels

Various attempts to classify social conflict by structural levels of social units involved focused on identifying types of parties in a conflict, as well as their relative positions within a wider social structure. Such classificatory attempts have been arrested by the absence of a universally accepted taxonomy of social units [5].

Authors tend to identify different numbers of structural levels of conflict. While, for example, Chase [16] distinguishes between eighteen levels of conflict, ranging from personal quarrels to inter-bloc conflicts, LeVine [17] differentiates between only four levels: intra-family, intra-community, inter-community, and intercultural level.

Boulding combines classification by structural level (individual, group, and organizational), distinction between spatially segregated and spatially intermingled groups, and differentiation between homogeneous and heterogeneous organizations, to obtain an eight-fold classification. This classification includes conflicts between persons, boundary conflict between spatially segregated groups, ecological conflict

between spatially intermingled groups, homogeneous organization conflict (e.g. state vs. state), heterogeneous organization conflict (e.g. state vs. church), conflicts between a person and a group, conflicts between a person and an organization, and conflicts between a group and an organization [18].

Dahrendorf combines a classification via social units (groups, sectors, societies, supra-societal relations) with a classification via structural conflict relations between parties (equal vs. equal, super-ordinate vs. subordinate, whole vs. part). The result is five times three, i.e. fifteen different classes of social conflict [19]. Conflict between a state and a criminal gang in this classification would be an example of a whole vs. part conflict on a societal level. Conflict between the East and the West – as in the Cold War – would be an example for an equal vs. equal conflict on a supra-societal level. We conclude this brief overview of social conflict classifications by structural level with Galtung's simple classification based on two dichotomies: individual vs. collective, and intra- vs. inter-system, resulting with a classification into intra-personal, inter-personal, intra-collective, and inter-collective conflicts [20].

2.2 Social Conflict by Interactional Aspects

Besides many structural classifications of social conflict, there is also a variety of classifications that focuses on the conflict's interactional aspects.

Bernard distinguished three general frameworks that differ in the general assumptions they make about the causes, nature, and resolution of conflict [21]:
- The *social psychological approach*, focused on tensions between conflict parties;
- The *sociological approach*, focused on costs for conflict parties;
- The *semanticist approach*, focused on misunderstandings between conflict parties.

Rapoport classified conflicts according to psychological and behavioral patterns inherent to conflict dynamics as [22]:
- *Fights*, which are dominantly non-rational, and primarily psycho-physiologically based on mutual fear and hostility, with the main objective to harm, destroy, subdue, or drive away the opponent;
- *Games*, which are dominantly rational, with the main objective to outwit the opponent;
- *Debates*, which are dominantly emotionally and ethically oriented, and primarily socio-psychologically based, with the main objective to convince the opponent.

Bernard's second attempt to classify theoretical approaches to social conflict moved closer to Rapoport's trichotomy for she distinguishes between [23]:
- The *non-strategic model*, roughly corresponding to fights;
- The *neo-strategic model*, roughly corresponding to games;
- The *anti-strategic model*, roughly corresponding to debates.

2.3 Schellenberg's Classification

A more encompassing view of these theoretical approaches has been offered by Schellenberg [6] according to a fundamental perspective from which these types of theories view social conflict. He distinguishes between:

- *Individual characteristics theories* understanding social conflict in terms of the nature of the individuals involved;
- *Social process theories* understanding conflict as a process of social interaction between individuals or groups;
- *Social structural theories* understanding conflict as a product of the way society is formed and organized;
- *Formal theories* seeking to understand human social conflicts in logical and mathematical terms.

Individual characteristics theories encompass a wide spectrum of psycho-physiological approaches to conflict including among others, socio-biological approaches, Freud's psychoanalysis, Adorno's authoritarian personality theory, and Dollard's frustration-aggression hypothesis.

Social process theories encompass a variety of economic approaches, such as Adam Smith's account of markets as interest-balancing mechanisms, Homans' social exchange theory, and Boulding's application of ideas from economics to more general social conflict processes. Schellenberg subsumes under social process theories also the works of Simmel and Coser, symbolic interactionist approaches to conflict, Lewin's field theory, Pruitt and Rubin's social psychological approach, and Kriesberg's and Northrup's works on intractable conflicts. Schellenberg did not consider to subsume Bernard's and Rapoport's attempts to classify conflicts by interactional aspects into this category.

Social structural theories encompass a number of approaches focusing on class, race, ethnic, national, gender, age, and other social-structural differences and their impact on social conflicts. Under this category Schellenberg classifies a wide variety of approaches including Plato, Marx, Weber, Dahrendorf, and other postmarxists, Madison, Morgenthau, Galtung, and Wallerstein. The earlier mentioned attempts at classifying social conflicts by structural levels would also fall within this category.

A somewhat awkward characteristic of Schellenberg's classification is that the first three groups of theories are classified according to an underlying theoretical perspective. By contrast, the fourth group is classified according to the manner of expression. In other words, the fourth group encompasses all formal theories, while the first three groups encompass mostly verbal theories, focused on individual characteristics, social processes, and social structure, respectively.

3. A Critical Discussion of Formal Approaches in Schellenberg's Classification

In what follows we review several formal-theoretical approaches to social conflict. We investigate how they relate to Schellenberg's first three categories. The motivation for this comparison is that we find no particular reason for why formal theories should not also have a theoretical value. We "unpack" these formal approaches and evaluate their theoretical content against Schellenberg's categories one, two, and three. The review encompasses game theory, system dynamics, statistical methods and econometrics (which will be henceforth called as a result of its omnipresence "conflictometrics"), expert systems, and agent-based social simulation.

We devote particular attention to agent-based social simulation. We see that it has potential to shed light onto the nature of generative processes related to social conflict, as well as to bridge the gap between some of the more learned approaches, which have often been treated as mutually irreconcilable.

Of all these formal approaches Schellenberg explicitly refers to game theory only. However, he also discusses Richardson's work on differential equations of arms races [24], which can be viewed as an early precursor to system dynamics, as well as Richardson's "Statistics of Deadly Quarrels" [25], which is a predecessor to what we label here as conflictometrics. The agent-based social simulation applications to social conflict have been developed more recently, i.e. after the publishing of Schellenberg's textbook.

3.1 Game Theory

Classical game theory can be described as a mathematical theory of the rational choice of courses of action which are directed toward certain outcomes, provided that all players in the game know each others' preferences regarding any possible outcome. The theory conceptualizes and lays down in mathematical formalism the more general approach of rational choice theory which sees aggression as a primarily rational response to given circumstances. Social conflict is thus conceptualized as primarily a conflict of rational interests.

Identities and interests – in game theory jargon "beliefs and preferences" – of game players are exogenous to the model and do not change over time. In terms of Schellenberg's classification, game theory is clearly more process than structure-oriented for it emphasizes how the opposition of individual interests unfolds through a series of strategic moves performed by game players. On one hand, the emphasis on interests opens further possibilities for conceptualizing conflict, but on the other hand the conceptualization is often cast in an overly mechanistic and inherently static mathematical form. Although the game-theoretic approach provided important insight into instrumental and strategic aspects of conflicts, it has been less adequate for analyzing human interaction when mutual dependence is part of the logical structure and demands some kind of collaboration or mutual accommodation between players [26].

When some of the requirements of classical game theory are relaxed, the approach becomes more dynamical. For example, in evolutionary game theory replication is introduced into a population of players, with players' replication rates depending on their payoffs in repeated rounds of the game. Evolutionary game theory treats strategic interactions as dynamical systems [27]. It therefore closely approaches system dynamics. Extensions of the classical game theory often, however, come at the cost of analytical tractability. The use of computer simulation helps to enhance game theoretical methods beyond the limits of mathematical tractability (e.g. [28]).

3.2 System Dynamics

System dynamics provides a framework for the application of a more general systems approach to social and economic problems by describing the behavior of a system using a set of differential equations [29]. This set of equations may be quite complex and it usually has to be solved numerically. Given initial conditions, the solution describes evolution of the system with time. Numerical calculation of the solution values in time is usually performed by computers and it is referred to as a simulation of

the system. Historically, system dynamics was the first approach to explore the methodology of simulation.[2]

System dynamics is generally concerned with a system as a whole. The emphasis lies usually on the ways in which elements of the system connect and interact with each other and on ways in which they function together. The system is given as a set of stocks and flows. These macro-variables describe the state of the system. The macro-variables are averages over micro-variables specifying the behavior of individual elements. Due to such top-down conceptualization, system dynamics cannot directly address conflict between the system's elements. Rather, when system dynamics methods are applied to conflict research, conflicts are usually conceptualized as special, "dysfunctional" modes of system behavior. The task of system dynamics then becomes to identify ranges of system parameters, which characterize such "dysfunctional" or "unstable" regimes [30].

Schellenberg classifies systems theory as a process-based approach on the grounds that it attempts to develop "a general method of analysis which could apply to the study of processes of organization, wherever they may be found" [6, p. 72]. Although the term "system dynamics" itself connotes dynamics and process-orientation, systemic structure in terms of interrelations between system's elements is fixed and exogenous to system dynamics models. The "processes of organization" considered by the systems approach in the social sciences are generally the large-scale processes running at higher systemic levels of a social system. In sociological tradition these higher systemic levels of social systems have been, more or less consistently, associated with the term "structure". Therefore we decide to depart from Schellenberg's choice of classifying systems approaches, and we classify system dynamics as primarily structure-oriented.

3.3 Conflictometrics

We understand conflictometrics as applying quantitative, most often statistical methods to the study of social conflicts in a manner that is similar to the ways econometrics is applied to the study of economic phenomena. The application of statistical methods to datasets obtained from large conflict databases enables scientific examination of various conditions which precede and/or co-vary with fluctuations in the incidence of conflicts [31]. The datasets used by conflictometrics contain data on the attributes of social entities, the relationships between and among entities, and the behaviors that these entities manifest vis-à-vis one another [32]. The most common social entities on which data has been recorded are nation-states. The relationships are usually situated on the international level, and the behaviors are political actions and events related to the occurrences of crises and conflicts [33].

Following Durkheim's terminology, we may say that conflictometrics aims at identifying and studying "social facts" of conflicts, which positions them closer to structure- than process-oriented theorizing. In contrast to individual-interactional approaches like game theory, the conflictometrics approach points to a broader social background within which individual interactions take place. Strong points of the conflictometrics approach include firm empirical grounding. The general intention is to uncover statistical relationships among the various variables on which data have been recorded, hoping that a better understanding of those relationships will enable

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[2] We use the term simulation as shorthand for computer simulation model, meaning a simplified computational representation of how a part of reality changes with time.

development of more reliable forecasting procedures. For example, it has been argued that "the close monitoring of prespecified events believed to be contributing factors to genocidal violence gives us a tool to predict the onset and magnitude of genocide" [34, p. 82].

Conflictometrics has also brought to the focus of scientific attention the probabilistic character of the relationships between various factors and the incidence and intensity of social conicts. Conflictometrics researchers argue that the field has advanced "at least to the stage of weather forecasting – that is, we can assert with some plausibility that certain conditions and actions lead to likely outcomes" [35, p. 102]. By combining such statistical-model-based with Delphi-type expert assessments, the accuracy of forecasts can allegedly be "brought beyond the 80% threshold, which is 'good enough' for some types of forecasts" [36, p. 303]. Critics of the approach point to the relatively weak explanatory power of conflictometrics studies due to their inability to specify how exactly independent variables causally affect dependent ones [37].

3.4 Expert Systems

The technology of expert systems has been developed by and was an important product of research in the field of artificial intelligence [38]. Like system dynamics, it attempts to describe whole systems. However, the specific property of expert systems is a rule or knowledge-based approach. Broadly speaking, expert systems seek to transform the knowledge of domain experts into (a web of) if-then relations. They provide an explicit framework for knowledge representation, which may be particularly useful for investigating the role of key decision makers in processes leading to or related with social conflicts.

In the 1980s a number of decision centered models have been developed by means of the expert system paradigm to analyze large scale social conflicts such as the Cuban crisis [39] or military dictatorship in Latin America [40]. Banerjee [40], for instance, applied a rule-based approach to model how cognitive schemata of Latin American military leaders result in typical categories of their social action. These possible pathways can be described as a set of if-then relations. Simulation then reveals that the dynamics inherent in these assumptions generate a stabilization of certain structural patterns.

Being grounded in artificial intelligence, this approach to simulation shares a number of features akin to agent-based modeling. In particular, unlike game theory or system dynamics, expert systems provide a straightforward framework for knowledge representation. The representation of individual actors, however, is rather limited. Like all systems approaches, expert systems have been preoccupied with system-structural considerations, with a particular focus on cognitive structures of systems under consideration. The ultimate purpose of expert systems is to diagnose system status. This delimits the capacity to represent the complexity generated by a vast number of individual interactions generated by individual actors. This is the particular strength of the object oriented programming paradigm that became popular in the early 1990s [41]. Agent-based modeling extended the artificial intelligence paradigm of expert systems to the paradigm of *distributed* artificial intelligence

4. Agent-Based Social Simulation as an Approach to *verstehen*

4.1 Agent-Based Models

In agent-based simulations agents, that is autonomous pieces of software, interact with each other in a virtual environment [42]. An important feature in the design of agent-based models is that not whole systems are modeled, but rather individual agents that are represented as separate objects and eventually together form a system of interaction [43]. For this reason the properties of the system need not be known beforehand [44]. Agents may vary in their complexity, but they have often been minimally required to possess a set of attributes and a set of rules governing their actions and interactions with other agents and the environment, i.e. governing their "behavior" (bounded rationality [45]). The way agents, their behavior, and interaction is represented is not restricted to numerical equations. Agents can generate their particular interaction histories and the simulation is not restricted to represent one ideal-type of agents as it can be discerned in the "representative actor" of economic theory. In fact, most agent-based models are a heterogeneous artificial society. Agents in social simulation – in all their simplicity – are devised to represent human individuals; groups in social simulation are devised to represent such social entities as families, groups, communities, etc. Agent-based simulations of social conflict address various phenomena covered by or related to the definitions of social conflict given in previous sections.

Actions and interactions of an agent may change the values of the agent's attributes, as well as the rules of the agent's behavior. These changes generally depend on the current values of the agent's own attributes, as well as on the (possibly complex) combinations of values of other agents' attributes. This kind of inter-relatedness of individual agents implies that complexity can thus be regarded as a characteristic feature of agent-based models [46]. The complex interdependence between the agents' (inter-)actions and attributes implies that neither individual "identities" (i.e. attributes and rules of behavior) of agents need be exogenously given, nor the structure of the system of agents need be built into the model in advance. Numerous non-linear interactions among heterogeneous agents, who are engaged in overlapping patterns of relationship, may generate macroscopic phenomena, for instance social structures or institutions, which may in turn influence the behavior of agents and their interactions at the micro level. Agents may both produce, and at the same time be a product of their "social reality" [47].

The mentioned properties of agent-based social simulation move this approach beyond the afore used classification of approaches to social conflict as individual characteristics-based, process-based, or structure-based. In particular, agent-based social simulation can be used to provide a computational implementation of theories belonging to each of these three groups, depending on the specific focus of a particular implementation. For example, individual characteristics theories may be implemented by giving priority to agents' "innate", i.e. built-in psycho-physiological attributes as predominantly determining their actions and interactions. Social process theories may be implemented by giving priority to agents' micro-level interactions as predominantly determining individual agents' attributes and rules of (inter-)action. Finally, socio-structural theories may be implemented by giving priority to macro-level structural properties of a "society of agents" (i.e. social norms, institutions, etc.) as predominantly determining individual agents' attributes and rules of (inter-)action. This points to the

possibility of combining features of different approaches within a single simulation model. We may, e.g., build an agent-based social simulation enabling both built-in agents' attributes and in-the-course-of-simulation emergent rules of interaction to impact behavior simultaneously. Such "combined assumptions" simulation models, and their results, may lead toward the synthesis of approaches heretofore regarded as mutually largely incompatible, and/or toward building a new, more encompassing and/or refined theory.

We do not want to argue that any of the previously mentioned approaches to social conflict is in any sense "optimal" or "most adequate". On the contrary, as Bankes *et al.* [48, p. 380] vividly remark: "By looking in many mirrors, each flawed in different ways, it is possible to see truths that no single mirror can reveal". In that sense we argue that agent-based social simulation provides a tool which enables "looking in many different mirrors" and getting insights into social conflict that "no single mirror can reveal".

A novel insight into a particular conflict, the one that "no single mirror can reveal", might be particularly useful for establishing a common reference framework for conflicting parties, which might in turn contribute to conflict management and conflict resolution efforts. Novel insights might be obtained, for example, by means of systematic comparisons between different (ensembles of) simulation models built on the assumptions of mutually different theoretical approaches. Such comparisons might indicate for which real-world situations some of the models/approaches are more suitable than others. Conflict management and conflict resolution practitioners might be particularly interested in relating various theoretical approaches to the "conditions on the ground". It has long been recognized that the game-theoretical framework is, for instance, more adequate for short-term "conflict settlement" efforts aimed at ending violence as soon as possible, rather than finding a long-term, sustainable, "conflict-transformative" solution [49]. Here, agent based modeling provides a tool to integrate knowledge from very different domains.

However, such expressive power of agent-based social simulation comes at a cost, i.e. in order to understand the simulated phenomena particular efforts have to be invested in monitoring and analyzing the underlying simulation process [50]. Results of simulation runs are often "fragile," meaning that it is not easy to inspect whether they are mere artefacts of specific parameter configurations or the really meaningful results [51]. In order to determine whether the conclusions from a given run are typical, it may be necessary to execute dozens of simulation runs using identical parameters (using different random number seeds) to determine just which results are typical and which are unusual [52]. Sensitivity analyses of effects of changing parameters of the model and systematic comparisons of different versions of the same underlying model usually require multiple sets of multiple simulation runs. Such analyses usually generate excessive amounts of "raw data" and, in order to make sense of these data, mastering special data analysis, presentation, and visualization techniques may be required [53, 54].

4.2 The Special Interest Group as a "Hall of Different Mirrors"

How agent-based modeling can contribute to the field of conflict research might be illustrated by the example of research undertaken by members of the recently formed SIG-SCSS. The group is focused on agent-based social simulation. Methodologically,

the SIG appears to be rather homogeneous. This viewpoint can be characterized by an emphasis on social complexity and emergence [55].

However, it can be stated that the topic of conflict is addressed from a variety of angles. SIG members contribute to the study of conflict from various perspectives, such as economics, computer and cognitive science as well as social psychology. Only a minority of researchers have a research focus on topics such as ethnic [56] or armed conflicts [57] and power structures [3] that are at the core of orthodox conflicts studies. Nevertheless, the thematic background of the SIG members reflects the heterogeneity of social phenomena encompassed by the notion of social conflict and provides for the above mentioned "multiple mirrors" in which the topic of conflicts appears.

For instance, research on economics might motivate investigation of conflicts over natural resources [58] such as water resources [59]. Moreover, questions arise if and how economic governance might support structural violence or social reconciliation [60]. Is the labor market shaped by an inherent conflict structure? These are examples of how an economic perspective reveals issues of social conflict.

Cognitive science and social psychology shed light on how micro and meso social relations might or might not lead to trust or mistrust and eventually violence. How can extremist opinions prevail [61]? How are dominance structures established [62]? What is the role of norms [63] and reputation [64] for both peaceful interaction and violent confrontation? Such questions motivated and keep on motivating the study of social conflict from the perspective of cognitive science and social psychology.

It also comes natural that a large proportion of SIG members have a professional background in computer science and/or artificial intelligence. There is an intrinsic relation between artificial intelligence and cognitive science. For instance, artificial intelligence provides advice to explicate mechanisms of escalation and de-escalation of crowd behavior [65].

4.3 Verstehen Social Conflict

The examples given above are only a small sample of the research questions studied by members of the SIG-SCSS. Of course, this is in itself only a small sample for all the research conducted in the whole field of social conflict. It nevertheless indicates the various problem areas underlying social conflicts of all sorts as well as the manifold perspectives to study such phenomena. This sheer diversity suggests conceptualizing otherwise overwhelmingly chaotic and complex amount of topics and perspectives by means comparable to the Weberian ideal type. Is it possible to identify underlying patterns in these various research fields without generalizing "too much too soon"?

In particular, a question for further research arises whether the technique of agent-based modeling reveals an interpretative framework for the phenomenon of conflict: the largely under-explored potential of agent-based social simulation lies in its ability to represent "interpretative" agents, adjusting their actions as a result of agents' recognition of and reasoning about macro-level phenomena [66]. This refers to the Weberian notion of *verstehen*: more intensive efforts directed towards modeling of how agents representing groups actually begin to interpret their relationship as conflictual could shed some light on the "second order emergence" [67] of meaning of conflict for its participants. It is also to be expected that such efforts would demand further development of and rapprochement between formal and narrative approaches to the study of social conflicts.

A natural conclusion from agent-based modeling giving formalized expression to Weber's idea of *verstehen* is that a potential common understanding of social conflict and how the study of it should be conducted can hardly be derived from the object of investigation's manifold instances. It naturally leads us to the insight that there are multiple realities that need to be understood by multiple approaches. The challenge remains whether a *verstehen* based approach to agent based modeling could integrate these approaches, reflecting a multiplicity of mirrors, into a common framework.

5. Conclusion

In this article we presented a synopsis of computational social science approaches to the study of social conflict. We used Schellenberg's conflict classification to home in the point that the types of approaches underlying conflict research also delineate our picture of the object of investigation. We then argued for the use of a complex systems approach by means of agent-based modeling to study social conflict. Research of ESSA's SIG-SCSS provided examples of how "multiple mirrors" are implemented in this tradition. An important reason why we rely on agent-based social simulation in the study of social conflict is the latter's inherent complexity. This approach facilitates gradualist generalizations in studying conflicts. Another reason is that we seek explanation and understanding. Agent-based computational social simulation affords *verstehen* in a Weberian sense, particularly by coming to grips with the second order emergence. Important steps have already been made in this direction, from participatory modeling to the use of agent-based modeling in analytical sociology, from empirically-driven models of conflict-torn societies to mechanism-based models of genocide. Further models will follow, contributing to a growing body of computational social science applications in the field of social conflict.

Acknowledgments

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