Computational models of emergent organisation in conflict environments

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Conclusion

As the current world faces many crises, societies will experience an enduring pressure to withstand the onset of violent conflicts. The increase of insurgency conflicts over the last decades demands continued high efforts and expenditures on peacekeeping, humanitarian relief and refugee support. Understanding the complexity of insurgency is necessary in order to timely detect the onset of insurgent organisations and improve COIN efforts. This dissertation focused on the analysis of the emergence of insurgent organisations through computational modelling. The potential and drawbacks of different modelling approaches have been identified and a novel multilevel modelling approach is proposed. In this section we will highlight the contributions of our work and discuss their implications and impact on a practical and theoretical level and discuss suggestions for future work.

6.1 Contributions

This dissertation shows how different computational modelling approaches can be used to analyse the complexity of insurgent organisations. Each chapter analyses significant complex dynamics of this insurgent behaviour. Our first contribution is on a conceptual level, as we identify distinct clusters of key factors to characterise insurgency through a multidisciplinary literature-based analysis. This literature-based analysis framework is used to assess the potential and pitfalls of existing computational models. We specifically address analytical, agent-based (ABMs), system dynamics (SDMs), and hybrid models (Chapter 2). Although the reviewed models have deficiencies, the literature analysis demonstrates the increasing capability of computational modelling methods to combine theory-driven explicit modelling and data-driven modelling approaches to understand the complexity of insurgency. For instance, SDMs are particularly suited for supporting the analysis of the impact of COIN at a strategic and operational level. An example of this potential is the model of Anderson [21] that analyses the different impacts of kinetic and non-kinetic COIN interventions on the growth of an insurgency. In particular, the SDMs enable modelling the contextual setting of an emergent insurgency conflict and the analysis of how this environment allows or facilitates particular forms of organisation. However, to grasp the underlying dynamics and to fully model the micro-level and meso-level dynamics of insurgency and put them in a system dynamics model is a challenge. An alternative modelling approach is ABM. ABMs are more focused on the human behaviour and social aspects of the conflicts, as they allow us to model individual characteristics and interactions to analyse emergent collective behaviour patterns. As such they enable analysing the actual effect of interventions on the actual organisational behaviour, which allows us to test the impact of COIN on a tactical and operational level. Foremost, ABMs enable modelling the processes and dynamics of emergent insurgent organisation. However, ABMs are often criticised for their lack of operational validity, as often calibration is not possible due to a lack of data. More importantly, the feedback mechanisms that characterise the complexity of insurgency conflicts seem absent in a majority of the agent-based models reported on in literature. The potential of hybrid models has been identified to deal with the challenges of ABMs to be able to analyse how COIN efforts are effected by contextual factors, such as demographic and economic dynamics, in the long-term.

Our analysis of the emergence of protests and riots during the COVID-19 pandemic (Chapter 3) contributes to the literature on violent conflict prediction. In particular, we show the added-value of system dynamics modelling to other data analysis approaches. The proposed holistic approach combines a theory-driven and data-driven approach. We empirically demonstrate the importance of accounting for the time-scale variability of societal factors and dynamics. Our model describes and characterises the dynamics of mobilisation and societal tension. These modelled dynamics can be calibrated using fine-grained datasets that include labeled incidents on a daily scale.

In Chapter 4 and 5 we show how novel agent-based models contribute to the understanding of the underlying processes of insurgent organisations. The proposed models are able to mimic the micro-level dynamics and show how these yield emerging self-organising behaviour. Our models build on the growing literature of agent-based models and dynamic network analysis to analyse insurgency as a bottom-up phenomena through modelling and simulation. In Chapter 4, contrary to other social network analysis or dynamic network studies, we combine a radicalisation process with the secrecy/efficiency trade-off for organising insurgent or terrorist networks. In such way, we analyse the impact of the dynamics of individual nodes on the organisational behaviour of a group, which to the best of our knowledge is neglected by current social network analysis. In Chapter 5, we analyse the temporal and structural dependencies in the organisation of illicit supply chains, and the impact of higher-order interaction on the adaptive capacity of insurgent organisations. In our analysis of insurgent organisations in Chapter 2, we identify structural adaptation, functional adaptation and resource flows as important characterising dynamics and attributes that need to be accounted for. The analysis of higher-order interaction and both interaction and intervention frequency reveals important pitfalls of analysing the resilience of decentralised organisation based on static network representations or simplified dynamics. To the best of our knowledge, this is the first attempt to explore the influence of higher-order interaction on the adaptive capacity of illicit organisations.

6.2 Discussion

In the first part of this thesis, we stated that computational modelling methods with a multilevel modelling framework provide the instruments to analyse the emergence of insurgent organisations. The insights of our literature analysis study outlined our approach to construct and evaluate the multilevel modelling framework. The wide range of macro-level, meso-level, and micro-level concepts that that are required to understand the underlying processes of the behaviour of an insurgency illuminate the complexity of the phenomenon. With our models we addressed and compared top-down and bottom-up approaches to analyse the inherent complexity of insurgency. We therefore developed three computational models. The second part of the thesis states that the computational approach can be used to analyse the dynamics of insurgency, specifically at different spatio-temporal scales. Understanding the temporal aspect of the dynamics of insurgent organisations showed to be essential to grasp and counter the adaptive capacity and resilience of these organisations. In general, while the emergence of insurgency itself is a decentralised bottom-up phenomenon, system dynamics modelling provides a more valuable tool to model the contextual environment and analyse downward causation of societal dynamics on the behaviour of the insurgents. Complementary to this approach, agent-based modelling enables the ability to actually model the micro-level dynamics to improve our understanding of the changing underlying interactions and relationships that are essential for the adaptive capacity of organisation. These insights have various theoretical and practical perspectives.

Through our review of models we have discussed the challenges of analysing insurgency conflicts. Our analysis was based on multilevel concepts to grasp the complexity of insurgency conflicts at large and organisational dynamics to describe the behaviour of insurgent organisations in general. The framework could be extended to analyse specific characteristics of categorised insurgencies, for example based on the functional character of insurgent groups that specifically aim to enrich themselves by destabilising and exploiting a specific area. Over the last years, insurgencies have often prioritised undermining tactics over sophisticated governmental tactics as they maintain a provocative strategy [24]. It can be argued that provocative insurgent strategies create the urge for quick repressive COIN strategies that are less effective in the long-term, as they might enlarge the disruptive effects of insurgent strategy [234]. As provocative insurgencies only aim to disturb and elicit violent COIN actions, the efforts to contain to the insurgency should be different and probably less aggressive . In particular, because these reactions impact the interaction with the population and may stimulate the growth of an insurgency conflict. On an operational level, extending the framework with specific goals and strategy of insurgencies enables us to better understand the functioning of insurgent organisations. In particular, their transitions between defensive and aggressive tactics have important implications, as it requires the insurgent organisations to functionally adapt, change logistically, and focus on other resource flows.

In summary, we provide a framework to analyse insurgency in general. This framework can be extended to analyse the dynamics of insurgency in more detail. We identify specific promises and pitfalls that we further address in Chapter 3, 4, and 5, where we specifically focus on the context of emergence of insurgent behaviour. Our modelling efforts in these chapters show the ability to construct computational models based on interactions, relationships and other dynamics that are extensively described in literature. These models show that is able to better explain and understand the complex phenomenon at various levels of detail which provides new opportunities. For example, analysing and understanding the implications and effects of disruption efforts in illicit supply chains is difficult due to the many changing attributes and interacting relationships and other dependencies. Our ABM models show the ability to explore these dependencies and specifically address the temporal aspect of this system. The development of the field of complexity and computational models over the last years, has brought forth various detailed theoretical and applied models that enable the analysis of the emergence of specific phenomena in complex adaptive systems with competitive environments. A possible different research direction opposed to our literature based modelling is to find analogies in other domains such as ecological models [26], as other systems might operate in a similar fashion. These models deal with similar dynamics of adaptation and evolution, and inspire researchers to cope with similar challenges in the scale and scope of modelling these complex interactions. Drawing out these similarities enables researchers to learn from the insights obtained from studies in other domains and extend these to models for the analysis of insurgency. For example, using developed predator-prey models to mimic the interactions between COIN, insurgent organisations, and the population could facilitate the analysing whether or under which conditions an insurgent organisation would be able to survive COIN efforts.

We have also focused on the potential of system dynamics for analysing the emergence of civil resistance (collective behaviour) in Chapter 3, and specifically its ability to analyse the impact of disruptive events. This research examines the effect of all macro-level concepts including legitimacy, deterrence, and contextual setting, on the micro-level dynamics. Understanding the interaction and time-scale variability in the insurgency dynamics is essential to grasp the inherent complexity of insurgency. With our statistical approach, we demonstrate the overdispersion of days without conflict which causes difficulties for predicting violence, specifically on a fine temporal scale. On the other hand, with our system dynamics model we aim to promote a different scientific habit of mind that critically regards dynamics on different time-scales in an effort to overcome these challenges. As such, we specifically model dynamics of societal 'tension' and 'pressure'. with this approach, we were able to identify proxy data for distinct features that either contain or trigger the development of these dynamics, and that enable cross-national comparison. As discussed in Chapter 3, the availability of extra data would enable us to improve these models. Specifically, we identify two aspects for data collection. First, for better estimating the character of fast dynamics we would require more micro-level, and meso-level data. For example, detailed and reliable data on the number of attendees of protests and riots is needed in order to better model the dynamics of mobilisation and recruitment or the emergence of new groups. We note that currently many initiatives to establish such datasets are ongoing, for example the Crowd Counting project that records participation of protests in the US [235], and the ACLED initiative to include labelling for emerging actors [154]. Second, maintaining and investing in datasets that capture violent incidents on a daily scale would enable to analyse the interplay of slow and fast dynamics. For example, previous efforts to analyse relatively slow dynamics of socioeconomic, political, or demographic variables demonstrate the importance of the dynamics that yield the ratio of elites in a society and its impact on the probability of conflict [129]. The interaction of such dynamics with the micro-level dynamics, or meso-level dynamics such as mobilisation are either underestimated or neglected as previous datasets were not able to capture both dynamics at the same time. Our holistic approach demonstrates the ability to model the contextual setting of emergent organisation in conflicts. The findings highlight that analysis should consider the time-scale variability of dynamics. Developing detailed datasets of COIN operations and contextual factors would enable the analysis of the potential impact of COIN interventions on the tension and pressure in a conflict environment, with a similar approach as our analysis of the perturbation of the pandemic on the society.

We have also showed how agent-based simulation enables us to model the micro behaviour and interactions. Simulating the behaviour of and among individuals allows us to understand the underlying dynamics of emergent organisations. Our review of agent-based simulations reported in literature shows that in earlier work the researchers involved either omit important feedback mechanisms, or focus less on the organisational structures. We specifically scope on the recruitment and structural adaptation dynamics. In Chapter 4, we model individual agents that influence the radicalisation dynamics of their neighbours, which effects the risk averse behaviour of the agents. As agents exhibit more insurgent behaviour they seek to foster cooperation and aim to recruit others in order to improve their operations, through networks that are based on kinship relationships. As cooperative interactions are potentially detectable by security forces, they provide both opportunities and threats. Insurgent agents balance the available opportunities and anticipated threats by optimising the number of connections in their cooperation network, which enables them to structurally adapt to COIN operations. As the analysis of our model shows, the dynamics of individuals and dynamics of insurgent organisational structures might have important implications for the effectiveness of COIN operations. In our model, insurgents are able to adapt from mechanistic organisation, that formalises rules and a chain of command to facilitate labor division, to organic organisation, that is less centralised and more flexible, in order to cope with COIN threats. Lowering the number of COIN efforts and allocating more resources to generate social opportunities may yield less insurgents, but more effective and mechanistic organisations. The results are comparable to real-world examples in which long-term relationships foster trusted cooperation and enable sophisticated organisation, but where COIN operations enforce fragmentation into smaller parts. Possible extensions of the model would enable the analysis of the consequences of more realistic or sophisticated insurgent behaviour, which we addressed in Chapter 4, or would allow to differentiate the effect of violent and non-violent strategies by the insurgents on the interaction with the government and noncombatant civilians as discussed in Chapter 2.

The evaluated COIN tactics that aim to disrupt the organisation of insurgents often focus on removing the most important individuals (nodes or agents) [217]. The application of social network analysis for insurgent organisations evaluating these tactics is often criticised for the artificial boundaries. Due to data limitations, analysts focus on identifying important nodes and characterising the organisational structure and functioning based on a static representation. However, the limited number of individuals in the datasets, which may include both individuals that are in the insurgent organisation and the noncombatants that provide contextual information, impacts the ability to test the resilience of these organisations. A limited number of entities, as in static analysis, is typical for analysing a phenomenon as a closed system. In reality, dynamics in the environment of the insurgent organisation impact the ability and ways in which they are able to recruit new members or plan their operations. The inability to take the replacement of individuals into account causes that all tested interventions are eventually effective as they diminish all (possible) insurgents. Modelling a radical open system requires including all relationships and connections of the modelled system with the dynamics in the environment [25]. Modellers are able to create a quasi-closed system in which boundaries are set that limit the openness of the system. Finding the right boundaries on the spatial and specifically the temporal scale enables modellers to reduce the openness of the system to a level in which the effects of system on the environment and the effects of environment on the analysed system are limited. While not being able to create a radical open system, that includes all societal dynamics, our models show the ability of the agent-based modelling approach to analyse the dynamics of insurgent organisations in a social contextual environment. The modelling efforts in Chapter 4 demonstrate the ability of agent-based modelling to account for important feedback dynamics that are having an effect on insurgent organisation. This enables us to model insurgent organisations that are able to recruit through kinship networks, while simultaneously the dynamics in the environment effect these networks. By continuously introducing new agents to the system, we are able to model the structural components of insurgent organisations as quasi-closed system in contrast to static representations. We extend this effort in Chapter 5, as we analyse the impact of the temporal scale of the dynamics of and on the networks. This approach enables to reevaluate the boundaries set to analyse the specific system. More specifically, it provides insights in whether the effectiveness of the interventions is impacted by the timescale of the dynamics of the system. We show that the effectiveness of interventions based on structure of the insurgent organisation depend on either the frequency of the intervention or the adaptation capacity of the insurgents. Therefore, it necessary to better understand the impact of the timescales of the dynamics of insurgency in order to identify strategies and tactics that are having a sustainable disruptive effect on their growth and operations. These findings confirm our intuition that COIN practises based on static network analysis should be reevaluated, and it advocates for the development of computational methods to further explore to what extend the dynamics of insurgency are impacted by spatio-temporal dependencies.

With our multilayered network analysis approach of illicit supply chains we are able to depict a more realistic representation of the relationships and dynamics of the underlying network organisation. This facilitates the previously described analysis, as we include the timescale of the organisational dynamics and different social and market relationships that are present in actual illicit supply chains. We further notice that insurgent organisations might benefit from resource pooling, for example by sharing cache points to stock improvised explosive devices [236]. As production, stocking, and deployment occur asynchronously, resource pooling would enable insurgent organisations flexibility to alter offensive and defensive tactics, but would induce more (temporal) dependencies between organisations. A combination of agent-based modelling and queuing theory would allow us to explore these dependencies. Furthermore, the model can be extended to explore specific market dependencies. For example, the distribution of weapons, or financially related resource flows could be restricted to a select number of agents due to skill dependencies, or dependencies in the physical domain (e.g. geographical dependencies). This allows strategical behaviour of the individuals to exert market power and demand behavioural change by other agents in exchange for required resources. In such way, the model provides tools to computationally analyse the emergence of hierarchical structures by fluid organisations.

6.3 Reflection and perspectives

Analysis of the emergence of insurgency through development of computational models challenges scientists to grasp the observed phenomenon at different spatio-temporal scales. Our analysis of literature and modelling efforts demonstrate the challenges of the field in terms of understanding the complexity and available datasets to replicate the underlying mechanisms. Technological advancements, globalisation, and changing environments offer insurgent organisations increased flexibility and adaptation opportunities. Intelligence aims to provide meaningful and trustworthy actionable knowledge about this adversary behaviour. Due to the complexity of insurgency, evaluation of countermeasures requires thinking ahead and account for the possible effects and reactions to these measures in order to anticipate on the adaptation and evolution of the adversary. Our analysis demonstrates the possible role of computational models to develop anticipatory intelligence, that provides means to anticipate and effectively counter insurgent organisation resilience behaviour in practice [117]. As outlined in the introduction section, (computational) modelling has various aims for practitioners, such as to guide data collection, discover new questions, expose prevailing wisdom as incompatible, or even offer near real-time crisis options. We highlight how system dynamics, agent-based modelling might offer practitioners with tools to pursue these goals.

Our analysis of the emergence of civil resistance demonstrates the value of system dynamics to analyse the contextual setting of emergent collective behaviour. Our approach of modelling social unrest as a emergent phenomenon includes theory-driven causal loop diagrams to capture assumptions on the causalities in the system and data-driven statistical and system dynamics models to test hypotheses. We applied a multi-methodology approach to integrate different perspectives from various disciplines on the complexities of insurgency. Such integration of psychological, social, economic, political theory is crucial to advance our knowledge on the interplay of different dynamics. This approach has the potential to facilitate analysis of the impact of security interventions on the social environment, and might help policy makers to identify similar drivers of the emergence of social unrest, civil resistance, and potentially insurgency. The adaptive and resilience capacity of insurgent organisations requires new methods to evaluate the effect of interventions on this behaviour. We have shown that agent-based modelling can be used to model the structural and functional adaptation of insurgent organisations, and challenge prevailing wisdom. In particular, the approach enables us to integrate various modelling approaches to analyse micro-level dynamics and interactions, such as behaviour models and networks models. Our results urges to further explore the feedback mechanisms between micro-level, meso-level, and macro-level dynamics. Specifically, developing model should aid in identifying and understanding the drivers of behaviour changes and the impact of efforts to enforce this change. For example, the different COIN strategies that have a enemy-centric, population-centric, or information-centric focus aim to have a different impact on the insurgency and the societal components. Our modelling efforts that include both organisational dynamics and contextual environment show that different modelling approaches better facilitate the analysis of these phenomenon on a specific spatial and temporal scope. Analysing contextual settings is not limited to the global or national scale, and could also help policy makers at a local, for instance municipal level to better understand how collective behaviour dynamics are intertwined with societal dynamics. Furthermore, modelling aids in guiding the data gathering process and creating evaluation criteria for intervention policies and strategy. As such, better understanding of the triggers of social unrest could help to allocate resources and timely plan operations. Subsequently, preventive policies could account for these developments and timely anticipate with aid, or services.

While computational models provide promising opportunities for policy making and evaluation, incorporation of these methodologies in the policy-making environment has important caveats that should be addressed in future research. Integration of system dynamics models, and real-time data would potentially allow us to develop explainable real-time systems that analyse state stability at various scales, such as global, national or regional level. Currently, specifically agent-based models are often challenged to achieve operational validity, due to limitations in data availability. Obtaining more (real-time) data on behaviour changes should spark the opportunities to validate both system dynamics and agent-based models. Our results suggest that these models potentially provide both insights in changes over time when supplied with new data, and the ability to generate insights in possible future scenarios using the simulation capability of the computational modelling methodologies. Various methodologies exist to integrate different disciples or facilitate collaborative modelling for policy-making, for example [237]. The review of analytical and simulation-based models provide interesting insights in the current development of available data. On the temporal scale, enduring efforts to capture conflict dynamics and incidents on a daily scale enable to better analyse the micro dynamics of insurgency. It should be noted, however, that it should always be evaluated that including more detailed interactions and dynamics remains relevant with regard to the specific research questions. More generally, a meta-description or abstract representation of the system rather than the daily dynamics of insurgent organisations might be more valid for addressing some of the relevant aspects of insurgency. Other developments, such as ACLED and CCC [154, 163], are broadening the scope of the data collection as they include non-violent events that impact the conflict environment. These developments might further enable to reevaluate the boundaries of analysing the emergence of insurgency as our analysis shows that the contribution of societal conditions to the emergence of protests and riots suggest that real-time system do not necessarily require data on a daily scale for all variables. Therefore, in order to validate a model of a network organisation and identify which variables that sensitive to changes in the environment, it is necessary to obtain a representative dataset that allows us to analyse the temporal effects of the variables on the network dynamics. Future developments in text mining and natural language processing could enable automatic extraction of information. We specifically address the usability of court sentences as reliable information sources to obtain detailed information about changes in behaviour by illicit organisations [238]. Additionally, for incorporating ABM in the policy-making environment it is required to develop adaptive ABMs that allow flexible calibration to specific contextual settings in order for ABM to applicable in real-time situations. A potential way to strengthen this flexibility would be to improve the validation of hybrid models, that combine the complementary value of system dynamics and agent-based models [115].