The application of complex systems concepts in a military context

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Abstract

Military peacekeeping and reconstruction missions become increasingly more complex. This complexity becomes apparent not only in the large number and variety in actors and domains but also in the intrinsic non-linear dynamics encountered in mission areas. To aid in a better understanding of this complexity we study the potential value of complex systems concepts in this context. This paper describes some of our preliminary insights and discusses some of the remaining challenges from an application point of view.

1 Introduction

In this paper we address some of our efforts to apply concepts from complex systems theory in a military peacekeeping and reconstruction context. In this context military decision makers are confronted with the complexity that comes along with the intervention aimed at the restoration of a safe and secure societal environment. This complexity becomes apparent not only in the large number and variety in actors but also in the non-linear dynamics intrinsic to a mission area that makes its causality difficult to understand. An example of this kind of complexity is the current mission in Afghanistan where coalition forces try to stabilize a country on the verge of a complete collapse [1]. Such stabilization includes the institutionalization of a majority supported Afghan government, the breakdown of anti-governmental entities like the Taliban and transformation of country's opium economy into a legal and sustainable one. From a military perspective the establishment of a secure and safe environment is a prerequisite for stabilization and successful transformation. However, due to the entanglement of domains, like for example the strong relation [2,3] between the opium economy and the powerbase of local powerbrokers like warlords a sustainable stability can only be realized by comprehensive consideration of possible interventions in all these different domains. This makes effective intervention an extremely challenging task requiring a combined effort throughout these domains and at many different scales and levels. Such a combined effort of multiple stakeholders goes far beyond the scope and time-space boundaries of traditional war fighting and more often than not relies on non-military actors and efforts. This broadening of perspectives challenges military decision makers and add to the perceived complexity of the problem at hand. One way of looking at the effectiveness of these missions is to consider the objective as a transformation process rather than just stabilization. Here, transformation refers to a move of a state or region from an undesired and harmful situation into a desirable configuration. Within such a view effective intervention contingencies should be aimed at those aspects that enhance the ability of a society to recover and adapt.

2 Complex systems and measures

As a first step towards applying concepts like alternative configurations [4] and transitions between them we adopted a methodology [7, 8, 9, and 10] for assessing resilience in social-ecological systems. This methodology recognizes the alignment between the transformation of systems and phase transitions and proposes a structured approach in identifying and analyzing these. Our hope is that by applying such an approach, military decision makers become better aided in analyzing and understanding the challenges that come along with the stabilization and transformation of regions. As an illustration of this analogy we'd considered the Afghan example as a two state system as depicted in Figure 1.

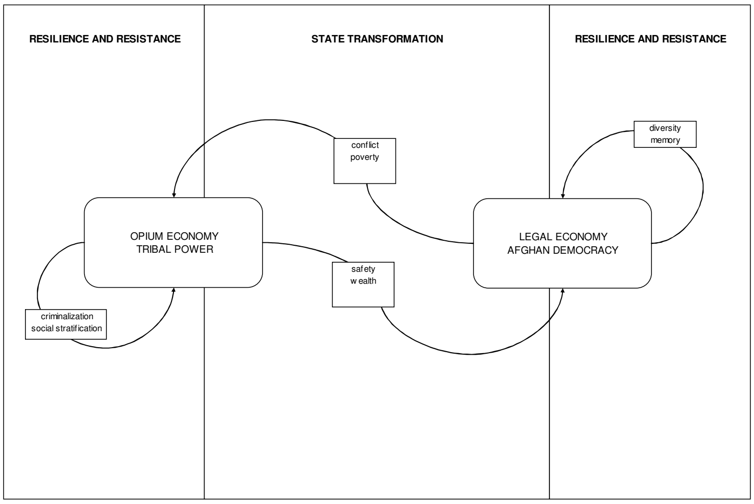


Figure 1 Above figure shows a simple diagram with the two configurations. Transitions between configurations are assumed to be governed by the crossing of a set of thresholds, in this illustrative example indicated by conflict and poverty thresholds. Crossing these thresholds and thereby moving the system into an alternative configuration can be seen as a transformative process, on the other hand, the resilience and resistance of the system in a particular state will actually prevent such transitions and try to keep the system in place. Examples of such influences include social stratification and criminalization associated with the opium and warlord dominated system. These influences hinder people to escape such an environment, effectively locking them into the system.

In this illustration, the opium and warlord-dominated situation is assumed to be one configuration, while a legal economy and Afghan democracy is considered as an alternative configuration. Next, aspects that maintain or reinforce a particular system state can be considered providing insight in what makes a system resistant to change and resilient to disturbance. From a transformation point of view, these aspects provide potential levers if one would try to erode resistance and resilience of an undesired situation, while in the mean time reinforcing those of the desired one(s). For example, in the Afghan case objectives could include the breakdown of the tight connection between the opium economy and powerbrokers by providing Afghan farmers with a means to escape the debt and poverty locks that keep them into this self-reinforcing process and by keeping them away from these locks by providing them with production and finance alternatives. Besides a focus on the determinant of resilience for a given configuration, the thresholds between configurations provide another important source of influence. We consider thresholds as those variables (or complexes of variables) that once passing beyond a certain level induce a significant change within the dynamics of a complex system, analogue to so-called bifurcations or tipping points [5]. Obvious, but important, examples of thresholds in the Afghan case are for example popular support for and trust in the Afghan government [6] or the efforts to establish this. The threshold effect becomes apparent by considering for example how poverty and failing governance has driven a proud Afghan people to a point at which the involvement in the opium economy has become inevitable and thus acceptable (see figure 2 for an illustration).

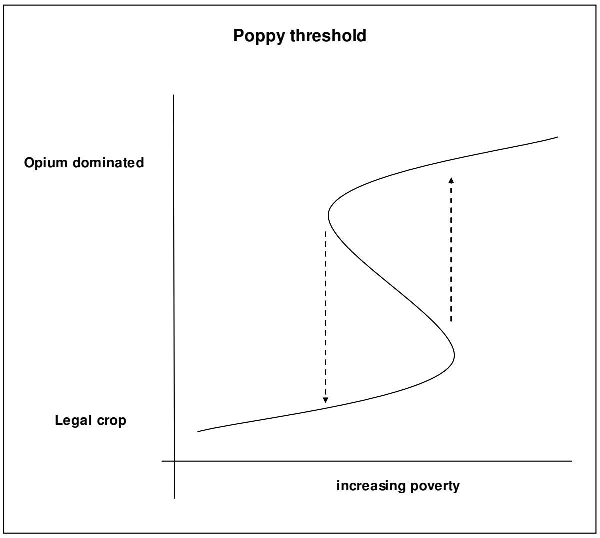


Figure 2 Schematic illustration of a hypothetical threshold variable (poverty) and its relation to alternative system states (legal or poppy dominated state). Note that the poverty level at which the system moves from legal to poppy is not necessarily the same as the switch from poppy to legal. Even though the poverty level may decrease due to increased earnings, a variety of factors like debt-locks and/or (tribal) peer pressure effects may actually keep farmers attached to poppy cultivation.

3 Indicators of change – a model based exploration

Although complexity is an often heard phrase and well recognized challenge in the military domain there is ample use of its underlying concepts. Therefore, besides our efforts to adopt a non-military methodology for observing and analyzing the resilience of systems within a mission area, we explored how these insights may potentially contribute to military decision making processes. In these processes, indicators play a crucial role, especially those that are associated with sudden changes in the dynamics within a mission area. To illustrate the potential value these kinds of indicators the concept of critical slowing down [12] has been explored. Critical slowing down is the observation that the return time of a system after a small perturbation tend to increase while approaching such a transition. As such, critical slowing down can be viewed as a measure of the resilience of a system.

We demonstrate this indicator using a simple, spatially explicit and military relevant agent model aimed at the demonstration of sudden outbreaks of civil violence [13]. In this model, the general public may decide to become rebellious (against an assumed authority) if their perceived hardship and legitimacy of the government crosses a predefined threshold. In this simple model, the switch of a civilian community towards rebellion can be seen as an example of a transition. One way to induce this switch is by varying the level of grievance of the individual agents either by reducing the legitimacy or by increasing the hardship of individual agents. Figure 3 shows an example of such an induced switch.

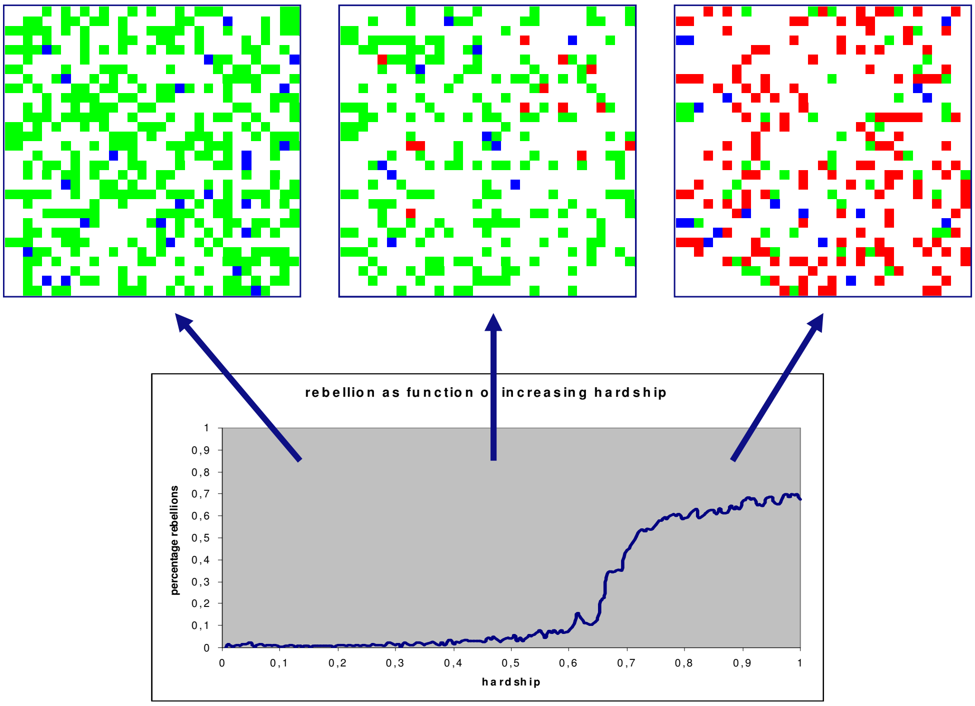


Figure 3 Results of a simulation showing the typical transition of the majority towards rebellion. In this particular example grievance is amplified by a slow increase in hardship (note that a decrease in legitimacy would give a similar result, see Epstein [13] for details). Top panel show screenshots of the various phases the system passes through. On the left the majority is non-active (greens, blue represent governmental forces like cops). While approaching the transition region, small outbreaks of rebellions (denotes by red cells) appears as shown in the middle screenshot. Once passing a critical threshold the majority becomes rebellious as is shown in the right screenshot.

To explore the occurrence of critical slowing down in our model we devised a simple Monte Carlo approach. To perturb the system, a fixed and proportional sized pulse press is applied to the hardship parameter of the individual agents. In successive runs this perturbation is applied at a decreasing distance from the transition region, thereby enabling us to measure the slowing down of the system. This critical slowing down is approximated by counting the number of simulation steps it takes before the system returns close to its original number of rebellions. For an example of the result from such a simulation scheme see Figure 4.

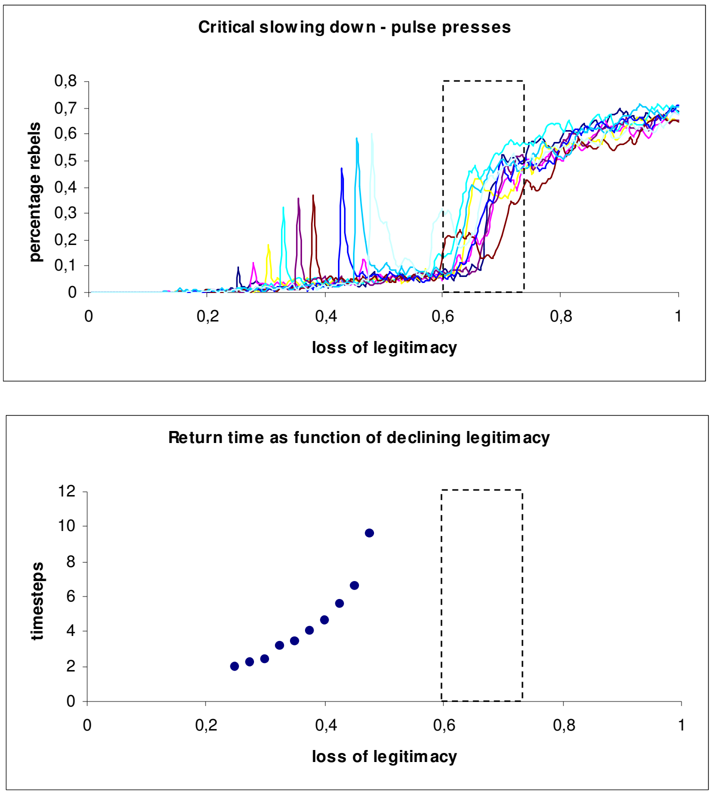
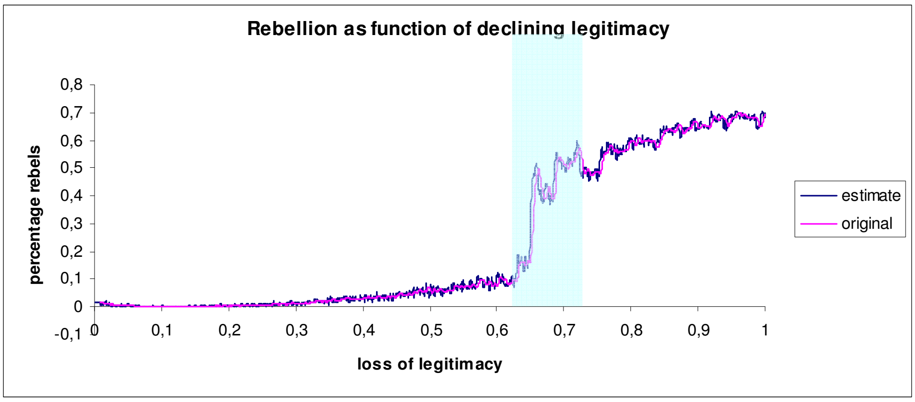


Figure 4 Demonstration of the increase in return time while approaching the transition region. Top graphs show the ten simulations with an applied perturbation at a decreasing distance from the transition region. Duration of the recovery is used as a measure for critical slowing down, as plotted in the lower graph.

Although critical slowing down seems promising as generic indicator for critical transitions a major drawback is the requirement for applying intentional perturbations to the system, which in the context of a societal system will be cumbersome. The use of approaches to approximate critical slowing down, like measuring autocorrelations [14, 15] in time series will relax such a requirement. Increasing autocorrelation is known to be associated with critical transitions and therefore can potentially serve as a generic measure either to identify transition regimes or to act as an early warning signal for transition. An example of how autocorrelation will increase while approaching a transition is shown in Figure 5.



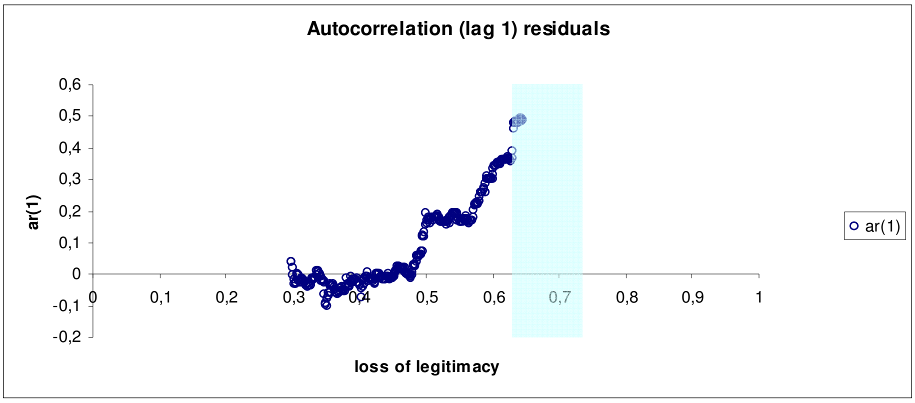


Figure 5 An example of the increase in autocorrelation lag 1 as approximation to critical slowing down near transitions. Simulated data is generated using the civil violence model. Autocorrelation of residuals is computed by smoothing the data, computing the residuals between original and smoothed data series and by calculating autocorrelations lag 1 of these residuals by using a sliding time window half the size of the period before transition.

4 Discussion and way ahead

In this paper we described some of our preliminary efforts to address the complexity met in today's military and humanitarian missions. To address the challenge of complexity in a military context we adopted a methodology for the assessment of resilience in complex systems. This methodology for assessing resilience, which heavily relies on expert group opinions, takes resilience as a fundamental guiding principle while describing and analyzing complex systems. In this context mathematical and numerical models serve as tools, rather than replicas of reality, that aim at structuring and stressing the expert's understanding of the real system. In such a way, models may reveal insight in essential aspects like drivers or thresholds within a system or highlight consequences of an expert's conception of the real system. To illustrate such a use we used a simple agent oriented model to demonstrate how these models could aid in a first exploration of phenomena in systems like human societies that are difficult to experiment with in the real world.

Understanding resilience, or the loss of it, may provide insight in how systems may or can move between alternative states. These transitions between states are often associated with particular thresholds and understanding a system's behaviour towards or away from these thresholds is of great operational value. Analyzing the dynamics of a system from this perspective may actually reveal an early warning signal for sudden change or indicate the existence of a threshold. Next, the identification and understanding critical transitions and their drivers within systems may reveal important insight for potential levers within a system. Since critical transitions can be induced by relatively minor disturbances they offer efficient ways transform systems as a whole.

Given the nature of critical transitions and their importance for understanding and inducing or preventing large scale change in systems these kind of measures may be of great value to decision makers. However, approaches to identify and monitor these processes are rather quantitative in nature, requiring reliable and continuous data and in the case of critical slowing down even may require active disturbance of the system (although the use of autocorrelations may bypass such a requirement). In our view this introduces a fundamental challenge in applying complex system concepts to real- world issues. Typically, many of the aspects we are interested in are associated with human (group) behaviours that, especially in mission areas, are very difficult to quantify in a scientifically sound and reliable way. In most cases decision makers like military commanders must rely on rather qualitative and subjective observations originating from analysts, experts and troops in the field. Dealing with these challenges will be subject of our future research.

References

[1] Rubin, Barnett J., 'The Political Economy of War and Peace in Afghanistan', World Development, 28(10), 2000: 1789-1803

[2] United Nations: Office on Drugs and Crime (2003), "The Opium Economy in Afghanistan - An international Problem", UNODC report

[3] United Nations: Office on Drugs and Crime (2004), "Afghanistan Farmers´ Intentions Survey 2003/2004", UNODC report

[4] Scheffer, M., and F. R. Westley. 2007. The evolutionary basis of rigidity: locks in cells, minds, and society. Ecology and Society 12(2): 36 Available online at: http://www.ecologyandsociety.org/vol12/iss2/art36/

[5] Brock, W. A. Repetto, R. (ed.) Tipping points, abrupt opinion changes, and punctuated policy change chapter 3 in Punctuated equilibrium and the dynamics of U.S. environmental policy, Yale University Press, 2006, 47-7

[6] Afghanistan in 2008: A Survey of the Afghan People', The Asia Foundation, 28 October 2008

[7] Walker, B., Carpenter, S., Anderies, J., Abel, N., Cumming, G., Janssen, M., Lebel, L., Norberg, J., Peterson, G.D., and Pritchard, R. (2002), "Resilience management in social- ecological systems: a working hypothesis for a participatory approach", in Conservation Ecology 6 (1): 14.

[8] Resilience Alliance (2007), "Assessing and managing resilience in social-ecological systems: A practitioners workbook", Volume 1, version 1.0, available online: http://www.resalliance.org/3871.php

[9] Resilience Alliance (2007), "Assessing and managing resilience in social-ecological systems: Supplementary notes to the practitioners workbook", Volume 2, version 1.0 available online: http://www.resalliance.org/3871.php

[10] Resilience Alliance (2007), "Assessing resilience in social-ecological systems: A scientists workbook", version 1.1 available online: http://www.resalliance.org/3871.php

[11] Carpenter, S.R. and Brock, W.A. (2006), "Rising variance: A leading indicator of ecological transition", in Ecology Letters 9(3), p. 311-318

[12] Nes, E.H. van, and Scheffer, M. (2007), "Slow recovery from perturbations as a generic indicator of a nearby catastrophic shift", in American Naturalist. 169, p.738-747

[13] Epstein, J.M., Steinbruner, J.D., and Parker, M.T. (2002), "Modeling civil violence: An agent-based computational approach", in PNAS, vol. 99 suppl. 3 7243-7250

[14] Dakos, V., Scheffer, M., Van Nes, E.H., Brovkin, V., Petoukhov, V., and Held, H. (2008), "Slowing down as an early warning signal for abrupt climate change", in Proceedings of the National Academy of Sciences, 105(38): p. 14308-14312

[15] Held, H. & Kleinen, T. Detection of climate system bifurcations by degenerate fingerprinting Geophys. Res. Lett., 2004, 31, L23207