Polish Political Science Yearbook, **vol. 52(2) (2023), pp. 113–128**
DOI: https://doi.org/10.15804/ppsy202321 PL ISSN 0208-7375
www.czasopisma.marszalek.com.pl/10-15804/ppsy

Piotr Baranowski
Adam Mickiewicz University in Poznań (Poland)
ORCID: 0000-0002-9598-7463
e-mail: pwmb91@gmail.com

Meta-Systemic Model of Transformation: A General Complexity-Based Approach in Political Science and International Relations

Abstract: System-based research remains an important yet usually outdated and internally contradictory approach in political science and international relations. Based on concepts borrowed from physiology, cybernetics, and general system theory, the system-based approach popularised in the 1960s was cast away as outdated and ill-focused. Despite those systems, the theory was developed in natural sciences, eventually creating a paradigm more applicable to domestic and international politics. The weakest element of past systems (like the one proposed by D. Easton) was that they did not allow for a sudden and catastrophic transformation and lacked emergence. This paper aims to present a model that would allow for the system's ordinary and catastrophic transformation. The complex adaptive system features were defined using relevant literature on a paradigm of complexity. Connecting it with the propositions of D. Easton, R. Axelrod, and M. Cohen, as well as R. Jervis, such a model was constructed. The theoretical introduction is supplanted with a general case study of the early phases of the Arab Spring in Tunisia. The model mirrors the complex systems' dynamics, considering the agent-structure problem.

Keywords: *Arab Spring, complexity, complex adaptive system, system, system analysis*

Starting in the late 1960s as a result of societal changes in the United States as well as changes in political science as a discipline associated with the decline of the behaviouralist programme, the mechanistic and inherently reductionist paradigm of political life gave way to new trends in research – a post-behaviouralist revolution as D. Easton (1969) called it, was underway. Both a movement and an intellectual tendency that was born out of "deep dissatisfaction with political research and teaching, especially of the kind that is striving to covert the study of politics into more rigorously scientific discipline modelled on the methodology of the natural sciences" was summarised by Easton in seven points. *The Credo of Relevance* (modelled after Easton's *Credo of Behavioralism*) underlines the most important differences the post-behavioural revolution was about to bring forward[1]. As much as the behavioural programme in political science was about to fade away as a mainstream approach to research, the system-based approach in science, in general, was not going to get extinguished, although before that system-based approach was seen as a product of the behaviouralist programme.

Interestingly enough, it has been the natural sciences (that behaviouralists admired because of their methodological ways) that eventually came back to political science to revive the system approach within it. Continuous import of new ideas from natural sciences enabled social sciences and political science in particular to look back at the achievements of system-based theories and evaluate them in the light of these ideas. Perhaps the most important concept that comes from outside of the discipline is the so-called complexity.

In this paper, I propose that synthesis between complexity and system-based theorising in political science and international relations is possible and inherently desirable. After all, the theoretical category of the system itself is the concept that seems to unify both approaches. Unfortunately, the fact that several disciplines are interested in the broad array of system properties does not necessarily make the synthesis automatically possible – there are systems in the natural world that have very little to do with human interactions and therefore offer no original insight into social dynamics. Fortunately, the compatibility of complexity and social sciences (especially political science and the study of international relations) hinges on the idea that system-based approaches in said disciplines and the study of complexity deal with the same kind of unit of analysis – the Complex Adaptive System (CAS).

Various researchers in the field comprehend complexity slightly differently, underlining selected sets of features of complex systems. Some claim that complexity (understood as a paradigm) can unify different philosophies of science that are at odds with one another, mainly modernism and post-modernism (Potulski, 2015, p. 40), as well as positivism and relativism (Johnaton, 2009, p. 139).

The following proposition draws from essentially three major components. The first one is the generalised tradition of system-based research in natural sciences often associated with General Systems Theory. These theoretical concepts were used to point out the roots

[1] The seven elements of the Credo of Relevance can be summarised in the following way: 1) Substance must precede technique – relevance and urgency are more important than sophistication; 2) Behavioural research conceals an empirical conservatism and does not pay enough attention to the context; 3) The main goal of post-behaviouralist is to break the barriers of silence that conceal "the brute realities of politics"; 4) Values are "inextinguishable parts of the study of politics"; 5) The task of an intellectual is to protect the human values of civilization; 6) The intellectuals bear responsibility for engaging in reshaping a society; 7) Organisations and institutions of intellectuals cannot "stand apart from the struggles of the day".

of complexity as an approach in its own right. The second component is the agent-based approach presented by R. Axelrod and M. Cohen, where authors introduce the key parameters concerning agents operating in complex systems like memory, strategy, location etc. The third and final part of the synthesis is system-based reasoning in political science and international relations, represented by the works of D. Easton, R. Jervis, and others.

A synthesis between system-oriented and agent-based approaches is a difficult process but necessary for a feasible explanation of any social phenomenon. As imperfect as this attempt may be, it is motivated by Wendt's comments posed in his landmark paper entitled *The Agent-Structure Problem in International Relations Theory* (1987, pp. 350–351), where the author introduces a structuration theory as a possible bridge between two distinctly different epistemological stances: individualism and structuralism, pointing out the possible commonality between them resting in an ontological layer, namely scientific realism. A similar claim has been made by A. Gałganek (2020, p. 223) in his recent work on the philosophy of the science of international relations. The author asked, "how much of a social structure needs to be added to the facts about individuals to explain a given social phenomenon?" which is linked with an additional question: "what is the ontological status of these phenomena?". This way author arrives at two epistemological stances found in Wendt's paper: individualism and holism. What differentiates Gałganek from Wendt is that he introduces a middle ground he called weak holism, where "a cause and an effect are situated on a holistic level, taking into account micro-fundamentals from the level of the individual. Scientific realism believes that some structures and mechanisms operate independently of the observer's capacity to grasp and manipulate it. Because of that: "acceptance of a deep realism means that the real basis for causality is the generative mechanisms of nature" (Gałganek, 2020, p. 235). Accepting a deep realistic stance and an "emergent ontology" leads to the inference that some entities "are subjected to the laws operating on more than one level". If emergence is added, one can conclude that "even though more complex layers of reality, say a society, are connected to the less complex layers, like individuals, in order to understand them, they cannot be reduced to the individuals". Therefore, if the ontological base for complexity is indeed a deep realism, the epistemology of individualism and holism (or structuralism) can find a middle ground.

However, any synthesis, especially in the form of an algorithmic graphic model, has to lean more towards one or the other. That is why the model presented in this paper is agent-based, but it includes elements from the level of the structure. The opposite operation is also possible when a model is based mainly on the structural level, including agent-level properties. These are essentially two sides of the same coin.

Choosing the works of David Easton as the basis for the complexity-based model may seem controversial since his model is based on cybernetics which is an earlier example of system-based reasoning than complexity. Nevertheless, it is the most well-known and one of the few models in political science that employs systemic principles in its design. In the preliminary stages of this research, it has been established that Easton's model shares some of the features of Complex Adaptive Systems, which again is not surprising because cybernetics and complexity share some concepts like feedback, the openness of the system, adaptive capacity etc. Easton's model lacks mostly emergence, so it is incompatible with complexity.

For the sake of simplicity, the components are not presented in this paper in great detail, as such presentation would most likely extend way beyond the confines of a single paper. Nevertheless, it should be stressed that understanding the dynamics of complex systems requires a detailed analysis of its roots, among which we find physiology, cybernetics, evolutionary biology and mathematics and within these concepts like system theory, homeostasis, feedbacks, equilibria, chaos, self-organisation, and most importantly emergence.

Complex Systems and Its Properties

System theory based on complexity requires a new system definition to be used effectively in political science and international relations. In the preliminary research, such a definition was constructed: the complex adaptive system is a non-deterministic, open system characterised by emergence. It is hierarchical, sensitive to initial conditions, able to self-organise, features mechanisms of internal distribution of changes that remain stable thanks to feedback loops, and has many potential equilibrium points. Change between these points is usually associated with significant tension, and after reaching a critical mass, that change is usually sudden and catastrophic. Because of the non-linear nature of the complex adaptive system and the presence of emergence, the system cannot return to its previous state. A complex Adaptive System is one of two types of complex systems (Holland, 2014, p. 39). The other one – Complex Physical System (CPS) – is inherently different, and as it does not display the adaptive response, it is not a useful tool for studying social dynamics. It seems that any approach to using CPSs to describe social dynamics is inherently bound to fail, just like quantum mechanics or Newtonian physics cannot tell us anything about human interactions (although many revered authors in the history of the discipline, like Thomas Hobbes – the spiritual father of realism in the theory of international relations hoped so) (Ball, 2004, p. 18). It seems that emergence and adaptation require an agency that Complex Physical Systems lack.

Some authors do not differentiate between CAS and CPA, focusing on their common properties. Mitchel (2009, p. 13) presents a three-fold definition of complex systems, arguing that they all 1) display complex behaviour (being a result of elements following a set of simple rules with no external control); process signalling and information (coming from their internal and external environment) adapt – change their behaviour in order to "improve their chances of survival or success". She also provides the simplest definition of a complex system: "a system that exhibits nontrivial emergent and self-organising behaviours".

The complex adaptive system is a category present in many disciplines. Because it characterises systems that interact with their environment, it is useful to model many units of analysis: from simple microorganisms to relations in vast ecosystems, from small groups of people to entire societies and their activities.

As mentioned, many authors attribute different features to complex systems. Potulski (2015, p. 40) presents 10 characteristics of such systems: 1) many heterogenic parts; 2) unexpected emergence; 3) sensitivity to initial conditions; 4) web structure; 5) agent-based dynamics; 6) ability to create new structures and patterns of behaviour; 6) non-linear dynamics; 7) adaptive capacity; 8) no visible boundaries; 9) co-existence of shared subsystems; 10) multi-level dynamics. Johnathon Louth (2009, pp. 140–141) presents a similar set of features, claiming that complex systems: 1) always create some form of order; 2) do not allow for long-term predictions; 3) are connected with an infinite number of eventualities; 4) do not pose fixed equilibrium that they strive to achieve; 5) are characterised by emergence; 6) they allow for qualitative evaluation. Antoine Bousquet (2011, p. 47) mentions: 1) non-linearity; 2) openness; 3) self-organisation; 4) emergence and feedback. Seva Gunitsky (2013, p. 39) proposes an even shorter list, claiming that complex adaptive systems are characterised by emergence, non-linear dynamics and co-adaptation. Gary Grobman (2005, p. 362) presents a slightly different list, mentioning: 1) aggregation; 2) ability to recognise and tag elements; 3) non-linearity; 4) existence of flows; 5) diversity; 6) ability to make predictions; 7) structure constructed of simple elements. Finally, Hind Benbya and Bill McKelvey present us with a table of features of complex systems according to other authors they looked at:

Table 1. Main characteristics of complex adaptive systems

	Holland (1988, 1995)	Axelrod and Cohen (1999)	Markovsky (1998)	Dooley (1997)
Large number of components	✓		✓	
Variation		✓		
Self-organization				✓
Diversity	✓		✓	
Dynamism and liveliness	✓		✓	
Adaptation to their environment			✓	
Interactions	✓	✓	✓	✓
Non-linearity	✓		✓	✓
Selection	✓	✓	✓	

Source: (Benbya & McKelvey, 2006, p. 18)

More contemporary literature on the subject does not offer a different definition of complex systems. Page (2015, pp. 24–25) calls complexity a phenomenological property arising from the behaviour of complex systems to which he attributes four features: the presence of diverse entities; interaction within a structure; interdependence of behaviour; capacity for adaptation. Condorelli (2016) describes complex phenomena as a "structure of relationship among elements of the system components" and mentions features like sensitivity to the initial conditions, self-organisation, adaptive evolution, unpredictability, non-linearity, and the presence of positive feedback. There is a vast literature where authors apply principles of complexity to their fields and focus on a selected element of the theory. For instance, Murphy (2014) applies complexity to the development of force structures in the US Air Force.

One of the most comprehensive works on the science of complex systems, praised by the Santa Fe Institute, is a monograph by Stefan Thurner, Rudolf Hanel, and Peter Klimek (2018, p. 22) entitled *Introduction to the Theory of Complex Systems* where authors approach the subject from a purely quantitative perspective, describing problems of probability and randomness, scaling, networks, evolution, statistical mechanics and information theory. Authors dissect complex systems providing a reader with the origins of each element that collectively make them ranging from physics, chemistry, biology, mathematics and social sciences. As a result, they define a complex system as a "co-evolving multilayer network". What follows are ten facts on the complex systems: 1) complex systems consists of multiple elements; 2) the elements interact with one another making up networks; 3) interactions are dynamic and change across time, and can be "physical, chemical, social or symbolic", the can also be "deterministic or stochastic" (which is consistent with the physical/adaptive differentiation); 4) the main characteristic of an element is its state, which is often scalar in nature; 5) states and interactions are not independent, they co-evolve; 6) co-evolvement is "usually highly non-linear"; 7) systems that are complex are also "context-dependent" when a process in one layer is connected to another layer contextually; 8) complex systems are algorithmic; 9) complex systems are path-dependent and non-ergodic (not getting the same results across time, or simply has a property that can be defined as memory that "stores and records the recent dynamical past of the system"); 10) complex systems have memory that can be stored in nodes (Thurner et al., 2018, pp. 22–23).

As a result of this preliminary research, taking insight from the various presented theoretical concepts, mostly originating in natural sciences, it has been established that Complex Adaptive Systems have nine distinguishable features. These will serve as an ideal type for further proceedings:

1. A complex Adaptive System is a non-deterministic open system. Such a system is connected to its environment, with other elements present. It is connected with these systems directly or indirectly. For example, in a system like a state, agents are connected in many ways, allowing for their interactions that shape the state's connection to every other state.
2. Complex Adaptive Systems display emergent properties, which makes them non-linear. Actors or agents form adaptive relations that change the entire system by changing themselves. Every interaction between these agents changes the context for future interactions. As a result, agents build structures that are irreducible to themselves. Structures, in general, predate the agents. Each interaction also increases the complexity of the entire system.

3. The very presence of complexity makes Complex Adaptive Systems sensitive to the initial conditions, as a change in these conditions creates a cascade of changes throughout the system. Such changes are not proportional and non-linear. Because there is no way to determine the initial conditions of such a system and because of the emergence, any meaningful predictions of future states of such systems are futile.
4. Every CAS is adaptive and hierarchical. Every system has a structure that limits the behaviour of its elements.
5. Every CAS is capable of self-organisation. The elements within the system enter into co-adaptive relations and create a structure which is then strengthened or weakened depending on the agents' actions. Each agent holds criteria for success and failure that help them orient themselves in the system.
6. Thanks to the mechanisms of the proliferation of changes, orderly systems in time are getting more orderly and chaotic ones more chaotic. It is universally recognised for all CAS: system-agent, system-state or international system. An organised system has many so-called attractors: agents are attracted by many issues to which they divide their time and resources. A chaotic system has a single attractor that engages almost all time and energy. The first system is characterised by the domination of negative feedback (between agent and structure), and the second by positive feedback. It is not clear how one system turns to another, although it is clear that systems thrive "on the edge of chaos", meaning that catastrophic change is always possible.
7. Every CAS has mechanisms that hold it within certain parameters. Usually, negative and positive feedback. On the state level, negative feedback is seen in the legal system and power apparatus, which limits agents' choices regarding their goal selection and viable strategies for goal attainment. A complementary mechanism is positive feedback, which is a source of change. In the political system, positive feedback is exemplified by elections, voting, protests, and revolutions.
8. Systems retain their stability by the mentioned feedback, which allows for many points where stability can be achieved. A response to the workings of this feedback is adaptation. Stability itself is not given but an effect of the adaptive behaviour of agents. If positive feedback creates changes beyond critical mass, the alternative point of stability emerges. Moving between the previous point of stability to the new one can be orderly or chaotic and violent. If the system possesses certain pathways of such change, it usually is not catastrophic (think about the change as a result of elections in democratic regimes). However, if change happens outside these pathways, it is usually violent and can crush the entire system in its given form.
9. CAS can never return to its previous state, as the order is always spontaneous and the relations that make it are unique.

Process of Transformation

There is a vast literature on political transformations, revolutions, and protest campaigns in political science. Although instructive on the level of a well-developed case study, it is not as useful when it comes to developing a theory of meta-transformation where the main vehicle is a theory of complexity. Comprehensive and frankly impressive works such as E. Chenoweth and M. Stephan's *Why Civil Resistance Works* (2011) or Chenoweth's *Civil Resistance: What Everyone Needs to Know* (2021) focus mostly on what makes a certain campaign successful in given circumstances. This paper underlines that a social system is essentially Complex Adaptive System, and therefore its transformation can be described by the attributes associated with the theory of complexity. Using the works of Easton, Kaplan, Jervis, and Axelrod is a logical choice since these authors seem to endorse system-based reasoning in their respective fields already. There is great utility in drawing from literature on political transformation and supplanting it with elements of complexity. Nevertheless, it is a monumental task which greatly exceeds the purpose of this paper which is general and introductory.

One of the main conclusions of the works of D. Easton, M. Kaplan, and especially R. Jervis and R. Axelrod is that there can be at least two orders of transformation of the political system (Easton, 1965, p. 109, 125, 143). Said transformation can be either adaptive or catastrophic. It is common sense that no CAS can stay the same for a long time because of changes in its environment it has to adapt to, and changes within. To keep functioning in an ever-changing environment, it needs to keep up with the changes and respond to them. As mechanisms of orderly, gradual, and evolutionary change are well-known and understood (Bertalanffy, 1984, p. 70; Wolfe et al., 2000, pp. 152–153; Querido & Gijn, 1994, p. 75), it seems that attention should be directed to the second type of transformation – relatively short and turbulent events on the edge of the system and its environment that are characterised by the uncertainty of the outcome (Poston & Stewart, 1978, p. 1). In social systems, such events are often mass protests or revolutionary activities.

According to R. Axelrod and R. Jervis, systems are populated with agents with a co-existing population of strategies. Agents act purposefully, meaning their actions aim to attain a certain goal. Agents can choose a strategy from these available to them in a given moment based on their location, abilities, memory, and other factors (Axelrod & Cohen, 2000, pp. 4–7). D. Easton and R. Jervis divide such a system into a political subsystem and its environment (Easton, 1965, p. 72). The political system provides a framework for agents' actions guarded by negative feedback. Agents act within these constrictions, trying to attain goals with selected strategies. According to participation theory, all agents are involved in structuring the overall system, even if they label themselves as apolitical (Karwat, 2017, pp. 60–67).

The preferred type of agent (from the state-system perspective) operates within limits prescribed by the system: they adapt by changing their physical and conceptual location and their aims and strategies, but only in ways that are allowed. It is not the case for all the agents. Sometimes an agent appears whose goals (or ways of attainment) contradict the norms. Such an agent has several ways to solve this contradiction. First, one can change the goal one is pursuing or the strategy he selected for attaining this goal; one can also alter one's physical or conceptual location. If that is ineffective, agents find themselves in a state of contradiction where one can try to change the system's rules using the mechanisms built into it. If that is not effective or indeed there is no altering mechanism that is accessible, an agent can decide to change the system anyway and establish new norms that would be more preferential. If, at the right time, an adequate number of agents act in unison, they create positive feedback towards the system, and as a result, the system itself moves away from its equilibrium state. The system's only responses at this point are to fold to the demands or use even stronger negative feedback.

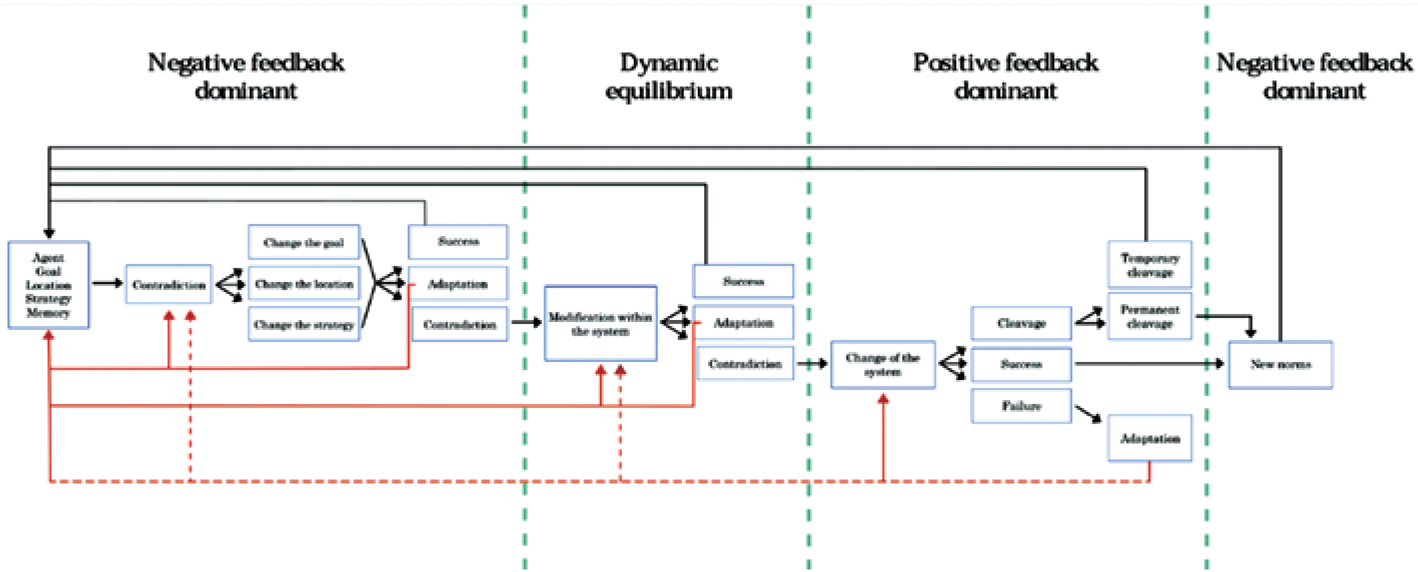
As the system's stability moves away from the equilibrium, the system can grow more and more divided, with more agents adapting to the changes, and as that happens, the system becomes more chaotic. At some point, a system can divide permanently, or one side can win and establish new rules, which starts the whole cycle again. The transformation process is non-linear; at any stage, agents are constantly adapting to the ever-changing environment. These series of changes are causing the catastrophic transformation of the system. The following dynamics are presented graphically:

Although the model presents a single agent, it is also useful for populations of agents: the processes and actions taken by a single agent are essentially the same as in a group of agents (although more complex). The agent's environment is populated with other agents acting under their parameters and roles in the system structure. The system maintains the structural limits as long as these roles are acted out.

The most vital feature of any agent is setting goals and the need for their attainment. To do so, an agent (following his experience and knowledge) continuously analyses his location in the system (both physical and conceptual) and selects the strategy to attain it. One also adopts criteria for success and failure to assess one's actions. As an agent tries to attain one's goal, one can select a different strategy (from a population of strategies available at that time), change one's location, or change the goal. It does not matter if the goal is attained: if an agent attains the goal, one adapts to the new situation and arrives in new initial conditions; if an agent fails, adaptation still takes place. This phase is characterised by the prevalence of negative feedback that an agent simply adapts to. Whenever adaptation is mentioned, it refers to the environment, as there is nothing else that the agent could adapt to.

An agent can conclude that one cannot achieve one's goals because of the systemic norms that limit one's choice of strategies and goals. It does not have to be objectively true, and such a conclusion is not immanent as agents operate in a state of limited knowledge and bounded rationality. If an agent acknowledges that the goals or strategies are contradictory to the system's norms, one can try to initiate a change of these norms: if the system is constructed in a way that allows for a change of its norms and the agent knows about

Table 2. Agent-Based Transformation Process of a Complex Adaptive System



Source: model based on literature review.

it. As the agent engages in the activity to change the contradictory norms, one constantly adapts and continues to change strategies, goals, and locations. An agent interacts with new agents, expanding one's knowledge and experience and modifying one's parameters as other agents do. Every interaction an agent engages in creates new initial conditions for one's future behaviour, just like every success or failure. This stage is characterised by a creative, complementary and dynamic equilibrium between negative feedback coming from the structure of the system and positive feedback coming from the agents that demand change. Even if positive feedback overpowers negative feedback, the change is still controllable and does not destroy the system. In other words, it is evolutionary, not catastrophic.

When the agent's goals are in contradiction with the system's norms and the agent is unable or does not want to attain them using permitted strategies (or one thinks so), one can conclude that the only way to make a change is to destroy the structure of the system that generate these norms. The agent starts to generate positive feedback, and if the circumstances are right: a large number of similar agents in a given place and time who follow a common signal generated by the agent(s) can select a common, self-reinforcing strategy to achieve a common goal the system can go through a catastrophic transformation. For that to occur, there must be a space for such transformation, as presented by E.C. Zeeman's machine (1976, p. 68).

The agents who play the role of guards of the political system generate negative feedback towards those who are generating positive ones to change the pattern or interaction (Axelrod & Cohen, 2000; Marszałek-Kawa & Dmochowski, 2021). The agents who generate this positive feedback may want to make a permanent cleavage, which would allow them to introduce new norms. They may want to create a border that would separate them from the previous system. If their feedback overpowers the one generated by the system, the division can materialise. If that division proves to be permanent new norms are being introduced, which initiates the restructuration of physical and conceptual space, which in turn forces agents to adapt. If, on the other hand, the cleavage is not permanent, the system stays in a state of high tension. The change at this point is inevitable since even if agents that desire change lose their struggle, their activity also forces adaptation on the side of agents trying to prevent these changes.

The systemic change is then a consequence of changes in the agents responsible for maintaining the norms in the system. The failure of agents who desire change also means a new adaptive cycle has begun. They might try again, this time changing their goals, strategy, location, or any combination of these parameters. All in all, if the catastrophic transformation did not occur and the norms within the system did not change or changed very little, the system went through an adaptive transformation. Unfortunately, the final assessment is only possible post-factum as there is no way to monitor these dynamics in real-time, partly because of the huge number of variables and even more crucially because of the inherent nature of CAS, where adaptation is a continuous process that happens independently in many agents at the rate that cannot be followed in real-time, if at all.

Any transformation in the field of international relations is even more complex than the one observed in the state system. The higher complexity comes from the fact that the agent who makes decisions in the international system operates in two systems at the same time, and because of the number of interactions they are involved in, the adaptive behaviour and co-evolution are more difficult to follow. They have to pay attention to what happens in their state-systems and other state-systems operating in their environment. Fortunately, this complexity does not change the basic assumptions of the presented model. The international system today is much more regulated than in the past, but it is still based on the relations between the agents that agree on acceptable norms to follow. It seems then that the only difference for the model is to assume that the agent is not a unit within a state-system, but a state in the international system. Like the single agent, the state-agent tries to attain its goals in the international system and can use the same mechanisms that a single agent can, except for changing physical location.

Possible Application

The presented model is general by design. Like any model in science, it underlines certain features and downplays others. Because of that, its explanatory power lies in framing particular events as one coherent narrative. It seems plausible that it will be most useful in explaining cases where catastrophic change was observed. One such series of events was the so-called Arab Spring – a series of turbulent protests that broke out in the Middle East and North Africa at the beginning of 2011. As much as I am convinced that the model can be used as a guide for a comparative case study of the Arab Spring, focusing on only one example may be enough to demonstrate the model's benefits (explanatory power) and drawbacks (its limitations). The case chosen here is the Arab Spring in Tunisia.

In the newest edition of J. Zdanowski's monograph (2020, pp. 330–331) on the history of the Middle East, the author evaluates the Arab Spring in detail, explaining that in the preliminary phases, all protests were a form of civil disobedience. He claims that the main reason behind the evolution of protests into more violent behaviour was an effect of the existing power balance between the authorities and the people. Based on that, he separates the protests into 1) ones that successfully overthrew the existing regime; 2) ones where authorities convinced people to cease protests in return for a promise of reforms; 3) ones where the violent response of the governments ended the protests by force. This particular division is also supported by a quantitative analysis of the Arab Spring performed by Andrey V. Korotayev et al. (2014). It seems, then, that where regimes fell due to public pressure, a catastrophic transformation occurred – the same cannot be said about other instances where protests were put down by force or people ceased to revolt voluntarily. Besides the existing power balance mentioned by Zdanowski, there is a host of other variables that influenced the dynamics and the outcomes of the protests: these are parameters of the agents, initial conditions of the system and the relations between the emergent complex adaptive system called authorities and the emergent complex adaptive system called society. In order to utilise the explanatory power of the model, it is necessary to move to the level of an agent, as the outcomes of the protests are inherently connected to his placement in the system (among others). It is also important to state that the so-called Arab Spring was a phenomenon that was far more complex than any previous protests in the region because of the role of technology that allowed protesters to organise themselves and coordinate their actions much more efficiently than ever before, which allowed for the even stronger positive feedback.

Muhammad Bouazizi was 26 at the time of the protests, and contrary to popular information, he had no higher education (European Parliament, 2011). He was the typical representative of Tunisian youth who was left out of the economic development that the region experienced in the last two decades (Ghanem, 2015, p. 41). At the age of three, his father passed away, and his mother married his uncle (New York Times, 2011). Buazizi worked in the informal sector, selling produce harvested on his stepfather's farm on the streets of his town. As his business was not registered from time to time, he was forced to pay bribes to avoid trouble (The Guardian, 2011). On December 17, 2011, a local municipal inspector named Faida Hamdi, the 45-year-old female, was trying to extort a bribe from Buazizi, which he refused to pay, and as a result, part of his produce and possibly a cart that he was selling from got confiscated (Time, 2011). It is also unclear how he was insulted, some sources say he was slapped in the face, and some say he was spat on, but there is no way of finding out. After the incident, Buazizi decided to file a complaint in the municipal office, but he was not even received. No more than half an hour later, he poured petrol on himself and committed self-immolation and, as a result, died on January 4, 2011 in a local hospital (Time, 2011). The act of self-immolation resulted in widespread protests that sparked thought the country, eventually ending the 20-year reign of a dictatorial rule of Zine al Abidine Ibn Ali.

Like any agent in a complex adaptive system, Buazizi had four basic parameters. He had a physical location – he was born and lived in the city of Bu Zaid in the central part of the country, a place of high corruption, high unemployment among youth and high levels of general dissatisfaction. He also had a conceptual location – he was a lower-class member, the single breadwinner in his family, and had only basic education. As an agent, he had goals to attain – the most important of which was survival and providing for his family. The strategy for that was selling products in the city centre. He was part of a larger network of agents similar to himself, so he operated and adapted to the changes in his environment. He also had criteria for success and failure and limited, localised knowledge of interactions between other agents in his environment, translating into limited rationality. When it became apparent to him that he could no longer attain his goals because the other agent dramatically changed his initial conditions through negative feedback, he decided that to attain his goals, he needed to change a rule of the system that put him in a vulnerable position. He opted for changing the system's rules with a systemic solution – he tried to fail a complaint to the agent's supervisor in the municipal office. When he failed at that because he could not get through a semi-permeable barrier, he probably concluded that the change he hoped for was impossible. Not being able to change any other parameters – most notably locations, not being able to change his goals, after going through an adaptive cycle, he changed his strategy again and went for self-immolation. Even though his action resulted in him removing himself from the population of agents, his strategy enriched the population of strategies available to other agents. His action sent a signal to similar agents, who picked it up and responded using their strategies to attain their goals. Because there was a large population of similar agents who started to self-organise and coordinate their actions, to begin with, the positive feedback eventually overpowered the negative feedback that authorities tried to generate successfully (promises of reforms, trying to curb the protests by force etc.). As the population of protesting agents grew, new agents with their own goals and strategies also joined the protests, eventually even including members of the regime apparatus – then the critical mass was reached, and as a result, Zine al Abidine Ibn Ali fled the country. Tunisian army first facilitated his escape and later took the side of newly formed authorities. The vacuum left by the dictator was then filled with agents that reacted to the new initial conditions created by the protests. On March 9, the ruling party was de-legalised, and on October 23, 2011, elections for the Constitutional Assembly were held (Zdanowski, 2020, p. 423). On December 10, a new interim Constitution was adopted, and two days later, a new president was elected (Moncef Marzouki). Finally, a new Constitution was adopted on January 26, 2014 (Zdanowski, 2020, p. 425).

The Tunisian state-system went through a catastrophic transformation, which resulted in new norms that were introduced. If the initial conditions for the agents were different, if the interactions among agents were different etc., it is possible that the entire transformation would not have occurred. It is even possible that transformation would be purely adaptive, like in states that settled for reforms only (for example, Jordan). Keeping in mind R. Jervis' remarks about the system effects (strategies of agents depend on strategies of others, it is impossible to do merely one thing), it seems like the events of the Arab Spring in Tunisia were unique because the initial conditions were unique as well.

The presented example shows that the model has limited, although visible explanatory power. As mentioned, it would be even more desirable to analyse all instances of the Arab Spring in all countries where it has occurred in a comparative case study. It is possible that it would prove the explanatory power of the model even further.

Conclusions

The complexity of the CAS presented in this model is even more striking when one considers that every system of this kind is in a state of continuous adaptive change concerning its environment and that the agents constantly change the environment. Thanks to that, the agent lives in a state of perpetual novelty and, as a result, perpetual adaptation. If every agent goes through an incalculable number of changes, the system is almost infinitely complex.

With that being the case, it seems naïve to think that there might be any analytical tool that could help a researcher comprehend the dynamics of any CAS fully – if by any change all the data could be collected, it is sure that at that very moment of making conclusions the data is already outdated. The researcher himself is also a CAS who constantly adapts to new stimuli, alters one's goals, changes location, uses memory, and selects strategy while interacting with the object of one's research. Once the research is finished, the researcher is a different person from who he was once he started.

If the basis for complexity is ontologically true, there is no way to make reliable predictions about future events. Naturally, one can build certain scenarios and try to work out their likelihood through tedious calculations. Nevertheless, one can never be sure that all factors were considered as it is just impossible. We know that interactions between agents are not random, but the number of possible outcomes is so vast that it looks almost infinite. If one adds the emergence into the equation whole endeavour seems almost pointless. At the same time, it is difficult to argue with a value of a truly systemic approach like this one.

That is why we propose that complexity (along with the proposed model) should be regarded as a meta-theoretical concept that should be considered while constructing any system-related synthesis. It can be convenient for any researcher: if an object or process being looked at can be defined as a Complex Adaptive System, one can draw directly from the paradigm of complexity and bypass endless defining and re-defining the object one is interested in. The greatest weakness of the model proposed is that it does not answer the most fundamental question – what is behind the mechanisms that are observable in such a system? It takes into account phenomena like emergence, but ultimately it is not reductionist. Where a desire to attain goals comes from? What motivates an agent to do something rather than not to do it? How does he orient himself in the system? How do others do it? What transforms occur? How does an agent select strategies? These and even more questions need separate detailed research, which needs to be carried out in various disciplines. The proposed model is just a skeleton, by no means perfect, and it is possible that for the sake of simplicity, it will have to remain on the meta-level indefinitely.

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