Method of System's Potential as Holistic Approach for CAS-Modelling

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INTRODUCTION

Multi-agent modelling (MAM) is traditionally used for modelling of Complex Adaptive Systems (CAS). Interaction of agents creates a new (surprising) patterns of macroscopic dynamics and regularities of the structure (so-called "emergent properties" (EPs) of a system) at macroscopic level. As a rule, activity of "intelligent agents" (IAs) is regulated by rules which imitate Darwin's laws of evolution (struggle for survival, the search for maximal gain). Computer simulations of models of real complex adaptive systems (such as stock markets, socio-economic and ecological systems) and data of real systems' behavior indicate that very dissimilar systems demonstrate the same EPs. Method of System's Potential (MSP) is a holistic method of CAS-modeling. MSP describes EPs as "thermodynamic" properties of a holistic system. MSP considers CAS as ensemble of interacting agents which evolves on the basis of some universal "thermodynamic" laws of evolution.

MAM-approach of CAS-modelling is based on imitation of Darwin's laws through algorithms of behavior of IAs. MSP postulates that evolution of a system (as holistic system) is regulated by Lamarck's laws of evolution. Lamarck's evolutionary laws can be formalized with the use of some fundamental MSP-notions: "potential of CAS" (accumulated stock of adaptive abilities of a system), "conditions for realization of potential" (available stock of conditions which promote to application of adaptive abilities in adaptive activity), "efficiency of system's adaptive process" (a share of potential which is exploited in adaptive activity) and some others.

MSP-notions describe macroscopic properties of CAS just as "temperature" and "pressure" in thermodynamics describe macroscopic properties of gas irrespective to its molecular structure. MSP-notions can be represented mathematically as MSP-variables. Universal EPs can be understood as a manifestation of "thermodynamic laws" acting at the level of a whole system. MSP connects "thermodynamic properties" of a system with Lamarck's evolutionary algorithms which regulate macroscopic dynamics of a system.

MSP formulate Lamarck's laws mathematically as the dynamical system of nonlinear equations for MSP-variables. MSP-Equations generate very complex dynamics consisting of irregular cycles with discontinuities (mathematical catastrophes) and sudden jumps in "an efficiency of a system."

BACKGROUND

Our world consists of diversity of complex adaptive systems enclosed into each other: ecosystems, economic systems, social systems, markets and so on. Any complex adaptive system contains a multitude of sub-systems ("agents") which interact with each other. We know from our experience that dynamics of real complex adaptive systems can be very complex: the periods of a sustainable development can be interrupted by sudden catastrophic events such as disintegration of systems or sudden decrease of their ability for adaptation (for example, stock exchange crashes and disintegration of states).

Numerous computer simulations of multi-agents systems were explored during the last two decades by scientists specializing in CAS-modelling. Although these computer models were constructed for different real systems almost all of them displayed identical macroscopic properties such as:

1. Punctuated equilibrium and self-organized criticality (Bak & Wiesenfeld, 1987; Henley, 1989; Drossel & Schwabl, 1992; Kauffman & Johnson, 1991; Sole & Manrubia, 1996; Amaral & Mayer, 1999),

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2. Discontinuous cycles and catastrophic jumps of macro-indices (Hommes, 2002; Epstein, 2002; Kephart, 2002; Lade et al., 2013),
3. Self-Organized instability and regime "edge of chaos" (Kauffman & Johnson, 1991; Kauffman, 1993; Bak & Sneppen, 1993; Sole et al., 2002; Kephart, 2002).

Universality of these macroscopic properties indicates existence of some universal macroscopic rules of adaptation acting at the level of a holistic system.

According to MSP the development of any CAS at macroscopic level (as a holistic system) is regulated by Lamarck's laws of evolution. Adaptive rules acting at the level of separate agents reflect Darwin's ideas about evolution. According to MSP-approach, adaptive rules acting at the level of holistic system basically reflect Lamarck's principles of evolution.

MSP is a "holistic" approach which supplements MAM "atomistic" modeling of CAS. MSP describes Lamarck's algorithms of adaptation using categories which generalize and summarize adaptive properties of agents and properties of environment in which they interact. According to MSP-approach, universal EPs of CAS listed above can be deduced from Lamarck's macroscopic adaptive algorithms.

MSP-MAM interrelation is similar to interrelation between thermodynamics and molecular theory. Just as interaction (and motion) of molecules creates thermodynamic regularities between macroscopic parameters of matter, interaction of agents creates macroscopic regularities at the level of a holistic system. In this sense MSP is "thermodynamic" approach for CAS-modelling.

MSP is "top-bottom" technique of CAS-modelling (Pushnoi & Bonser, 2008) which supplements MAM "down-up" modelling of CAS. Macroscopic and atomistic levels of adaptive process of CAS are interconnected by non-trivial "circular causality" (this connection is similar to definition of philosophical "substance" as "causa sui" (latin)). Upward causality (from properties of "agents" and environment to macroscopic regularities of a holistic system) and downward causality (from macroscopic regularities of a holistic system to properties of "agents" and environment) connect macroscopic and atomistic level of adaptive process of CAS. MAM-approach explores generally upward causality ("down-up" modelling of CAS) whereas MSP-approach focuses on the opposite problem of downward causality ("top-bottom" modelling of CAS). According to MSP-approach the action of Darwinian adaptive algorithms at atomistic level of CAS depends not only on local environment and properties of separate agents but also on macroscopic state of a holistic system. Global MSP-variables (regulated by Lamarck's laws) impact the adaptive properties of separate agents and their local environment whereas these local properties as a whole also impact the global MSP-variables.

There are many examples illustrating interrelation of macroscopic and microscopic algorithms of adaptation of SAS. The attack threat onto the country (the dangerous influence onto holistic socio-economic system) change peace rules of adaptation in citizens (agents) onto enthusiasm of self-sacrifice for the sake of the Homeland ("top-bottom" causation); "social revolution" which changes macroscopic properties of socio-economic system is the example of "down-up" causation.

MSP-approach for CAS-modelling was proposed in 2003 year (Pushnoi, 2003) and was developed later in series of publications (Pushnoi, 2004a, 2004b, 2005a, 2005b, 2010; Pushnoi & Bonser, 2008).

MSP-APPROACH FOR CAS-MODELLING

Basic Definitions

Concept of "fitness landscape" (or "adaptive landscape") which came from evolutionary biology is used in MAM-approach for the modeling of agents' behavior (Wright, 1931; Kauffman & Levin, 1987; Kauffman, 1993). Each agent tends to maximize parameter ("fitness," "gain") which describes the success of agent in his struggle for survival. This process can be depictured as goal-seeking motion of agent on "fitness landscape" in direction to "fitness peak."

MSP introduces three macroscopic MSP-categories (MSP-notions) by means of which adaptive process can be formalized at a level of holistic system. MSP argues that macroscopic effect of agents' adaptive search can be described by means of the following notions: