Towards Conceptually Novel Oscillating Agent-Based Simulation of the Relationship Between Cultural Participation and Social Capital

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Abstract. Effective simulation and prediction of the social impact of culture is one of the most important questions in contemporary social science and formative cultural policy. After a comprehensive review of the current simulation approaches, we found an evident lack of systematic conceptual models, however. It gave an impetus to investigate some novel conceptual approaches. In general, we admit that cultural events take part in the formation of social capital via the ability to communicate behavioral information in social networks. Following the bottom-up approach, implications of the social impact of cultural events are taking place on the individual (agent or actor) level first. Consequently, the aggregated effect can be simulated and predicted for the group or society (multiagent) level as well. For several reasons, we used CIDOC-CRM cultural ontology, which gives a structured framework of main cultural entities. We discovered that relations between them are not trivial and require fundamentally different viewpoints and simulation frameworks, which would better conform to the emergent complexity of social networks. For this reason, we analyzed in more detail Youri Lotman's semiosphere concept and OSIMAS (an oscillations-based multiagent system) paradigm. Consequently, in the proposed agent-based conceptual model, there is employed not only classical pair-to-pair based Axelrod's neighborhood interaction model but also a one-to-many information broadcasting model. Such conceptual approach is able to provide simulation models for the complex emergent relations between cultural participation and social capital.

Keywords: Cultural participation · Social capital · OSIMAS · CIDOC-CRM · Conceptual model

1 Introduction

Cultural processes are defined as complex dynamic structures of a systematic nature (Lyman 2007). They can be analyzed in contexts of various sciences: philosophy, culture, anthropology, psychology, communication and information, political science

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(Kroeber et al. 1952). Equally, in the various contexts of theoretical and different fields of science, the impact of cultural events, products and services on personal and social change is under consideration (Fujiwara et al. 2014; Hill et al. 2008; Stanley 2006; Taylor et al. 2015).

In analysing the processes of cultural impact on society, the impact of cultural participation on social capital (including social cohesion) is one of the processes that is especially important for the development of society (Armbrecht 2014; Galloway 2009; Partal and Dunphy 2016). Common cultural experiences (as a kind of communicative practice) act as a 'social glue', making society resistant to challenges and mutagenic factors, such as 'linkages between the quality of social capital and a society's ability to discover and implement sustainable development, including a better range of solutions to conflicts over competing uses for natural, social and human resources' (Helliwell et al. 2014). The level of social capital also is an important indicator in quality-of-life measurements (Rogers et al. 2011; Engbers et al. 2017).

However, the researchers who explore the relationship between cultural participation and social capital notice a clear correlation between these two groups of variables. This is particularly striking in relationships between participation in cultural groups and civic behavior, participation in cultural events and trust in institutions, membership in cultural groups and interpersonal trust. And these correlations are more pronounced in the community than at the individual level. However, these correlations (by themselves) do not show a causal relationship (Delaney et al. 2005; Torjman 2004). Thus, the development of methods for establishing a reasonable relationship between participation in cultural events and social capital (and also social capital related social cohesion) is a major challenge for this kind of research. Thus studies on relationship between cultural participation and social capital are important for evidence based cultural impact assessment, rational strategic planning and public policy interventions, including the use of public funds for culture, cultural industries, and creativity.

The paper is developed as part of the project "Social Impact of Cultural Processes: Development of Metrics, Conceptual and Simulation Model". The main goal of research is development of measuring metrics and a conceptual and agent-based simulation models aimed the investigation of the social impact of cultural processes. This paper aims to consider the problem of communicative sharing of social capital through cultural participation, offering the conceptual model of the social impact of dynamic cultural processes as interaction of actors and events. The purpose of the conceptual model is to understand reality-based, social capital construction/deconstruction through cultural events impact, and to provide simulation models for the complex emergent relations between cultural participation and social capital.

The article uses the CIDOC-CRM terminology. The most important terms of CIDOC-CRM are also semantically related to the terminology used by ABM (Agent Based Modeling). For instance, CIDOC-CRM actors can be interpreted as agents in the MAS terminology.

The conceptual model limitations presented in this article, are as follows: the impact of public and mass cultural events (concerts, etc.) on the actor is investigated, but not the effect of individual events (such as creating a poem, publishing or reading a

book, etc.); the study examines the effects of cultural events (via viewing, participation), but does not investigate creative effects of the events on developers and co-authors; the conceptual simulation model deals with the interaction between real-life cultural events and actors (agents) without taking into consideration the events posted on social networks. These limitations are mostly due to the evidence-based restrictions of the employed metrics and feasibility of empirical modelling of simulated processes.

This article is organised as follows: the first chapter discusses the conceptual model (methods, entities and variables) used for explanation of the processes and mechanisms involved in the relationship between cultural participation and social capital. The next two chapters are devoted to discussion of the possibility of applying the Y. Lotman's semiosphere and the OSIMAS (an oscillations-based multi-agent system) paradygm to provide a more precise explanation of the processes of sharing of social capital through cultural participation. Lotman's conceptual schema can be used for the theoretical elaboration of the structures and relationships connecting cultural participation and social capital. Meanwhile, OSIMAS can provide a conceptual means to simulate and investigate various complex and dynamic processes.

2 Conceptual Model

2.1 Methodology

Conceptual modelling is applied to capture relevant aspects of the research topic and for understanding how cultural participation and social capital are related. In our research, we understand "conceptual model" as "an abstract representation of something generalized from particular instances" (Borah 2002) as "a simplified representation of real system" (Liu et al. 2011). It works as "a kind of proto-theory <…> which can then be tested for validity [and] can often help in working through one's thinking about a subject of interest" (Bates 2009). On a methodological level, this conceptual model is created using the CIDOC-CRM methodology. According CIDOC-CRM, a conceptual model consists of two categories of informational elements: (i) classes, describing the concept for an entity, as 'categories of items that share one or more common traits serving as criteria to identify the items belonging to the class' and (ii) properties describing the concept for a process that 'serves to define a relationship of a specific kind between two classes' (Le Boeuf et al. 2015). In this research both elements are derived from the results of a systematic literature review and meta-analysis (performed by authors). The conceptual model was developed as a formal ontological specification of a conceptualisation that is amenable to understanding the relationship between cultural participation and social capital.

For a standardized description of the conceptual model we use generally accepted MAS (multi-agent system) ODD protocol (Grimm et al. 2005; Grimm et al. 2010). This protocol consists of three blocks (Overview, Design concepts, and Details), which are subdivided into seven elements: Purpose, State variables and scales, Process overview and scheduling, Design concepts, Initialization, Input, and Sub models. In the sequence, for conceptual modelling we use Overview block.

2.2 Entities

Based on the theoretical considerations, the social impact of cultural processes is understood as a systemic, targeted process, that can be estimated via dynamics of the social capital. In the course of cultural events, the added value of social capital is created, which generates the social impact of cultural processes. The entities, variables and relationships pertaining to the cultural processes are illustrated in Fig. 1.

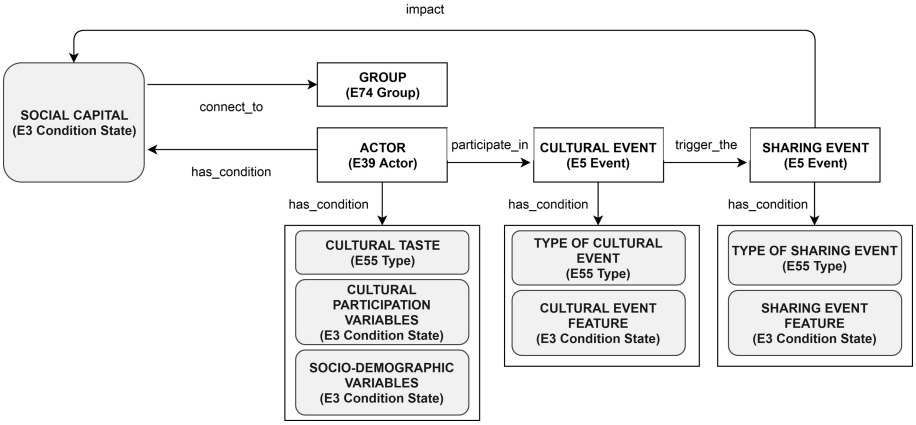

Fig. 1. Entities, variables, and relationships of the model of cultural process.

In the conceptual model, three basic level cultural process entities are distinguished and formalised as CIDOC-CRM classes: individual actors (CIDOC-CRM, E39 Actor), cultural events (CIDOC-CRM, E5 Event) and sharing actions (CIDOC-CRM, E7 Action). A cultural event is perceived as a temporary entity that 'comprises changes of states in cultural, social or physical systems, regardless of scale, brought about by a series or group of coherent physical, cultural, technological or legal phenomena' (Le Boeuf et al. 2015). The concept of 'cultural' can be analysed in various contexts (Kroeber and Kluckhohn 1952). For this research, 'cultural' is understood in a narrower sense as a set of agents' individual attributes that are subject to social influence (Axelrod 1997) and actions performed by agents within cultural domains that are 'a set of practices, activities or cultural products centred around a group of expressions recognised as artistic'. The ESSnet-CULTURE final report lists heritage, archives, libraries, book & press, visuals arts, performing arts, audio-visual & multimedia, architecture, advertising and art crafts (Bina et al. 2012). In the conceptual model, the cultural domains could be generalised as three types of cultural events: high culture, popular culture and sport. The concept of high and popular cultures is based on Pierre Bourdieu's theoretical framework that links different 'cultures' with the theoretical concept of cultural capital (Bourdieu 1986). Meanwhile, sport as a separate event type is defined as 'an activity involving physical exertion and skill in which an individual or team competes against another or others for entertainment' (Sport 2019). Sport as a cultural practice was introduced on the basis of (i) widespread public administration

practices that institutionally and temporarily link culture and sport (e.g., UNESCO theme 'Sport') and (ii) the significant impact of sport events on the public in the context of the social capital formation (Taylor et al. 2015).

The actors are defined as 'people, either individually or in groups, who have the potential to perform intentional actions of kinds for which someone may be held responsible' (Le Boeuf et al. 2015). These actors were perceived as adaptive intelligent agents that had an objective, interacted with the environment and with each other and created communities that were able to make decisions depending on the changing environment and their internal conditions. In the conceptual model three types of individual actors, coherent to the types of cultural events, are distinguished. The main criteria of the actors' typology is the cultural taste concept based on research by Wright (2015) and Lizardo (2006). In the conceptual model, actors have three types of cultural tastes: high culture, popular culture, and sport. The actors could be presented individually and as groups (Person and Groups) connected with two representations of social capital (individual and group) that defined a person as 'real persons who live or are assumed to have lived' and a group as 'any gatherings or organisations of E39 Actors that act collectively or in a similar way due to any form of unifying relationship'. Additionally, 'a gathering of people becomes an E74 Group when it exhibits organisational characteristics usually typified by a set of ideas or beliefs held in common, or actions performed together' (Le Boeuf et al. 2015). The groups have a network structure and it basically corresponds to the structure of the social agent network, based on the Agent Based Modelling (ABM). In the conceptual model, the interaction among groups is based on several spatiotemporal patterns: it falls within (contains), in which all members of one (smaller) group are also members of the another (larger) group; it overlaps with, when a part of members of one group is at the same time members of another group; it is separated from, when none member of one group is a member of another group (Le Boeuf et al. 2015).

The third class of entities at conceptual model is the sharing actions, in which one actors share the social capital with another. A sharing actions are 'actions intentionally carried out by instances of E39 Actor that result in changes of state in the cultural, social, or physical systems' (Le Boeuf et al. 2015). In the conceptual model, sharing actions have two types of interactions: the participation in the broadcasted cultural events or by neighborhood interaction among agents. In the context of the OECD model, this sharing should be treated as "social network support" (Scrivens et al. 2013).

2.3 Variables

In the conceptual model every entity (actor, cultural event and sharing action) is described via variables (CIDOC-CRM, E3 Condition state). According to R. Axelrod, these variables describe features or dimensions. For each feature there is a set of traits that are alternative values the feature may have. This abstract formulation means that two individuals have the same culture if they have the same traits of features. The formulation allows us to define the degree of cultural similarity between two individuals as the percentage of their features that have the identical trait pattern (Axelrod 1997).

Individual actors in the model are described using constant (sociodemographic) and dynamical (cultural participation and social capital) variables. In the case of our conceptual model, constant variables are quite common demographic variables: gender, age, education, gaining and location (living place). These variables are important (in correlation with cultural taste) in determining agent involvement in the cultural event.

The dynamic variables correspond to the frequency of participation at cultural events and the four forms of social capital outlined in the OECD scheme (Scrivens et al. 2013). Cultural participation is defined using UNESCO's cultural statistics handbook as 'participation in any activity that, for individuals, represents a way of increasing their own cultural and informational capacity and capital, which helps define their identity, and/or allows for personal expression' (Ellis et al. 2012). In the case of this research, this definition is described in a more detailed form using the CIDOC-CRM as people's participation in a cultural events that alters 'states in cultural, social or physical systems' (in this study's case—resulting in changes in social capital) (Le Boeuf et al. 2015). The variables and values of the measurement of cultural participation is derived from the ESSnet-CULTURE methodology (Bina et al. 2012).

This study's definition and measurement of social capital adopts to the Organisation for Economic Cooperation and Development's (OECD) definition as 'networks together with shared norms, values and understandings that facilitate cooperation within or among groups'. The definition includes the OECD's proposed four distinct interpretations of social capital: Personal relationships, Social network support, Civic engagement, and Trust and cooperative norms (Scrivens and Smith 2013).

Each cultural event is described using sets of features which influence the choice and impact of the cultural event. The important choice features include price, event time, event place, popularity of a creator, and efficiency of advertising. In the conceptual model, these cultural event variables are constant along with the individual agent constant variables that determine his preferences to participate in a particular type of cultural event. The cultural event impact features are event span, frequency, number of spectators and number of performers. In the conceptual model, these are variables that enhance or weaken the impact of a cultural event on the individual and the public.

Each sharing action is described using two features (variables) - temporal and intensity. The temporal variable means that the sharing action happens over a limited extent of time: the duration (time span) from beginning to the end. In our model the sharing actions are perceived as contiguous (without gaps) whereas intensity means the relative level of interactions among individuals in sharing of social capital values. It is important to note that social capital is different from other forms of capital (Robison et al. 2002). Unlike some other forms of capital (with both private and collective benefits), social capital does not decrease when sharing. However, the potential effect of 'satiation' with social capital is possible; social capital is not additive, so its values do not change linearly. In this case, despite the intensive sharing of social capital, the individual's or group's social capital values no longer increase. It can be said that the process of sharing social capital through its mechanisms is closer to the process of sharing other non-material goods (e.g., information) than sharing financial capital. In the conceptual model the sharing of social capital is realised as not less than two types

interaction: by participating in broadcasted cultural events and by means of a neighbourhood of a network of actors). These interactions differ in duration and functional mechanisms. Broadcasting as an interaction is shorter, performed during the event in a time span equal to the cultural event, when one actor communicates and shares social capital with others, thus changing the social capital values for both sides. Meanwhile, actors who are not participating in the event can change values of their social capital only through communicating in neighbourhood networks with the agents who participated in the event. In comparison, broadcasting has a much faster and stronger effect than sharing through neighbourhood interactions (longer, less intensive and functionally a reduction in time). It should also be noted that the implementation of a neighbourhood network is twofold: (i) actors who tend to interact with another actors similar to them (a neighbourhood based on cultural similarity; this type of neighbourhood is not fixed) and (ii) actors who tend to interact with another actors who are physically close to them (a neighbourhood based on a physical network; this type of neighbourhood is fixed).

3 Conceptual Model Design Using Semiosphere and Pervasive Information Field Approaches

Review of the related literature has revealed that the core process of social capital formation depends on shared actions that promote communication of behavioral information. Traditional communication and information network research methods can be applied for modeling such processes. However, these methods are general and have to be specifically tailored to model emergent complex social phenomena like social capital dynamics. It is essential to apply these methods in a suitable conceptual framework, however.

There are very few research papers dealing with quantitative modeling or agent-based simulations in this research domain. It can be associated with the complexity and lack of quantitative analytic approaches. Difficulties stem from the lack of (i) suitable quantification methods, (ii) meaningful measuring metrics, and (iii) causal relationship between cultural participation and social capital.

The current research methodology is mostly limited to a disparate survey analysis of cultural participation and social capital estimates over large populations. Such investigations can lead to the correlation estimates, but do not explain causal relations. Besides, they do not strive to model how empirically observed social phenomena can emerge from the bottom-up interactions between agents.

Therefore, we propose a broader conceptual research framework aimed at the extension of the current understanding. It gives some new insights and tools for the quantitative metrics and bottom-up agent-based modeling. In this regard, we propose a framework of two mutually well-matching theories, i.e., semiosphere theory, initially developed by Lotman (2001) and OSIMAS (an oscillations-based multi-agent system) paradigm proposed by Darius Plikynas (Plikynas 2016), see Fig. 2 (illustration A). The figure also depicts the main object of investigation, i.e. modeling of cultural participation impact to social capital.

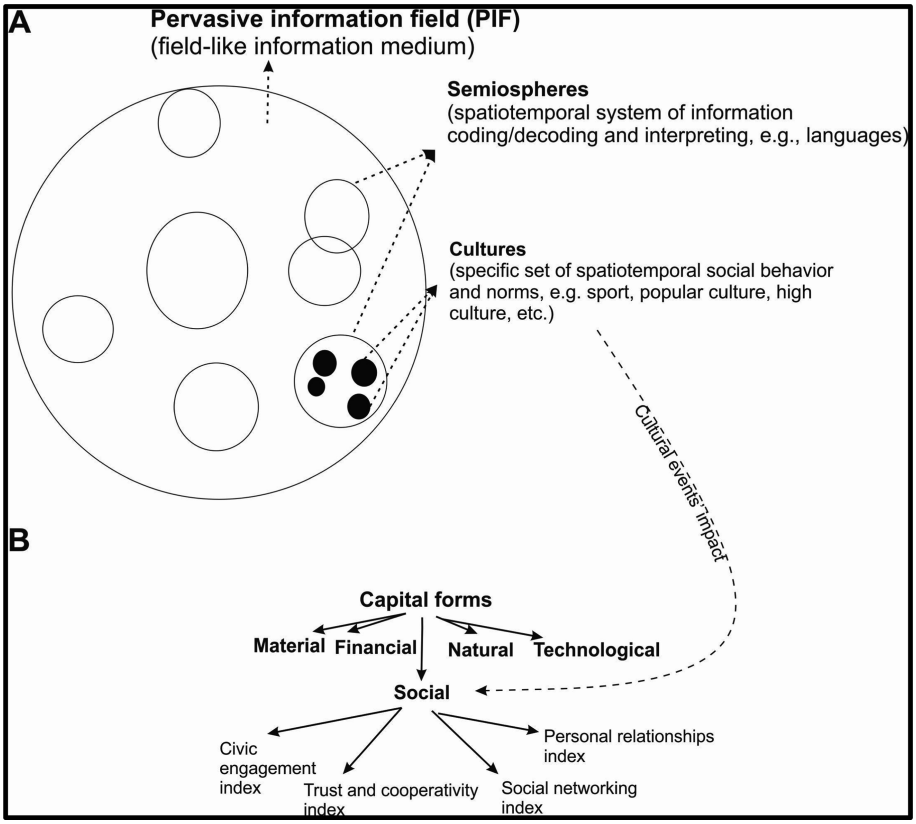

Fig. 2. General scheme of the conceptual model design. Illustration A depicts PIF, semiospheres, and cultures. Illustration B relates cultural events impact to the formation of social capital.

Lotman's conceptual schema can be used for the theoretical elaboration of the structures and relationships connecting cultural participation and social capital. Meanwhile, OSIMAS (an oscillations-based multi-agent system) paradigm can provide a conceptual means to simulate and investigate various complex and dynamic processes (e.g., clustering, cohesion, radicalization, marginalization, etc.) taking place in social mediums (Plikynas 2016; Plikynas and Raudys 2015). The application of OSIMAS paradigm as the theoretical framework provides the means to model a social information network as a pervasive information field (PIF), where each network node (agent) receives pervasive (broadcasted) information-field values. Such an approach is targeted to enforce indirect and uncoupled (contextual) interactions among agents to represent broadcasted cultural information in a form locally accessible and immediately usable by network agents. Therefore, the social system can be modeled as a pervasive information field, where each social information network node receives pervasive information-field values (Plikynas et al. 2015).

Such conceptual framework enables not only development of the metrics for the informative and communicative process of sharing information and exchanging meanings that happen during cultural events in a particular spatial-temporal volume but also provides means to simulate neighborhood interaction in a physical and social capital spaces. In these spaces, individual actors (agents) can operate (i.e., make decisions) according to their demographic and social capital characteristics.

The spatial-temporal volume could be perceived as Y. Lotman's semiosphere, where specific information coding (system of signs and symbols meant to convey information) is taking place. In some sense, semiosphere acts like a self-organized organism of codes, which are created, maintained, and interpreted by agents belonging to that semiosphere. Meanwhile, PIF (pervasive information field) provides a framework of physical universal oscillations-based methods - like phonons, resonance, quantum entanglement, etc. – as a means to model the code.

The interoperability between semiosphere and PIF hypothetically can be represented into levels: (i) abstract (as concepts, universalities across different spatial scales and time horizons) and (ii) concrete (as measured dimensions on particular spatial scales and time horizons). On the abstract level, the interoperability between semiosphere and PIF is formulated using six basic propositions:

1st Proposition. Both, the semiosphere and PIF, are similar informative items. In this regard, the primary functions of semiosphere are to communicate existing information, to generate new information, and to preserve information. Meanwhile, PIF, as a universal medium managing all kinds of multifaceted information, serves for information storage, dynamic distribution, and organization.

2nd Proposition. Both, the semiosphere and PIF, are related to the collective behavior of the conscious and subconscious mind-fields of individual members. In this regard, the semiosphere works as a global semiotic system that integrates all possible (produced by humankind) signs, texts, interpretations, symbols, information, knowledge, representations, and their relationships, including their interaction with the non-semiotic elements from outside of the semiosphere. Meanwhile, PIF, serves as a medium for a collective mind-field of self-organized social level, with the inheritance of some degree of coherent (synchronized) field-like behavior.

3rd Proposition. Both, the semiosphere and PIF, function through information sharing. The information sharing in semiosphere is based on a semiotic presumption about "signs reality", when people share not the information in "pure" sense, but coded symbols meant for decoding and interpretation. For instance, text is understood as an orderly system of signs meant for coded communication. Such coded communication system is distinct from other coded communication systems like visual, audio or tactile captions.

It is important to note that, in the context of Yuri Lotman's semiosphere theory, the texts are perceived not as stable reality objects (with permanent and immutable attributes), but - more like a changing function, acting through the creator, audience, context, and other interactions. The members of particular semiosphere become encoders and interpreters at the same time. They have the capacity to broadcast information for other people (using signs, and codes) and to read the signs left by other people (Lotman 2001). Meanwhile, PIF functions as a pervasive information network, where each network node (agent) receives pervasive (broadcasted) information field values. Social

information is coded and spread via social network almost at the speed of light via broadcasting telecommunication networks. The individual members of a society can be modeled as information storing, processing, and communicating agents in an information network society. From another perspective, information societies operate through agents, which are complex, multifaceted self-organized information processes composed of mind-fields of quantum field-like processes originating in brains.

4th Proposition. Both, the semiosphere and PIF operate in a spatiotemporal framework. The spatiotemporal synchrony is a prerequisite for effective real-time communication between agents. Semiosphere, being an open system, is constantly evolving and has a kind of "memory mechanism", which preserves the elements of past conditions or their fragments. For PIF the social order, i.e., self-organized and coherent behavior in social systems, is not so much correlated with the particular patterns of agents' actions, but with the synchrony of their mental activity. That synchrony can be compared to the physical model of superposition of weakly coupled oscillators. Synchronicity is involved in the social-binding problem (how information distributed among many agents generates a community). The social binding process can be imagined as a spatiotemporal resonance state. The contextual information there is distributed in fields, and fields although expressing some global information are locally perceived by agents, who are but a self-organizing part of the same PIF (Plikynas et al. 2015).

5th Proposition. Both, the semiosphere and in some sense PIF are multicentered structures with entirely relative centers and peripheries. The concepts of the center and the periphery in semiosphere are depended on particular (chosen by the investigator) observation point of two structures' interaction. Thus, the same semiosphere structural element, at the same time, can be perceived as the center in terms of one interaction and as the periphery in terms of the other interaction. However, in any case, we find the most developed and most structurally organized elements in the centers, where symbolic coding (e.g., languages and texts) system well operates. In the PIF approach, informational fields are operating on the square, rectangular, or other lattices consisting of a set of nodes. Size of the lattice is arbitrary. All resources and agents are distributed only on these nodes. Each particular node represents a point on virtual lattice space, which functions are for discrete time intervals to evaluate incoming fields and produce corresponding spectra representations, and to oscillate at own fixed natural frequency emanating it to the surrounding PIF.

6th Proposition. Actors of both, the semiosphere and PIF, are trended to semiosphere's creolization (Lotman 2001). In semiosphere, the centers are specific "canonical" structures, which almost eliminate the creation of new texts. Meanwhile, the periphery is the most important and (from the research point of view) the most interesting space of structures interactions (according to Yuri Lotman - texts creolization), which generates the major part of new information. These cultural interaction processes remind not a one-way reception, but they are more like multifaceted, pulsating, sign dialogue between the object and the subject (very relatively defined). According to Yuri Lotman, in order that the two different sign systems' cultural semiosphere structures interact, there must be a blurred boundary between "our own" and "foreign" structure, which usually occurs when one (internal) structure "learns" the language of the other (external) structure (Lotman 2001). Meanwhile, PIF proposes a set of universal physical methods for modeling interaction mechanism between agents. For

instance, a trade-off between entropy/negentropy, a stylized phonons model for quantification of oscillatory energy, resonance theory for harmonic oscillators, and even quantum entanglement theory, etc. (Plikynas 2016). Primarily PIF serves as a medium for all information encoding using one or another oscillatory framework, stemming from the physical complex oscillatory networks research. In PIF, each agent absorbs incoming wave packets, superposes them (producing unique spectra), and then transmits them to the environment. The center and periphery here can be understood in terms of synchronization patterns of oscillatory phases.

The prospective development of metrics, measurement, and simulation of individual and group-wise interactions using semiosphere and PIF principles is provided in the discussion below.

4 Sharing of Social Capital in the Framework of Coherent Oscillatory Paradigm

Investigation of the implicit oscillatory nature of agents and social mediums in general can reveal some new ways of understanding the periodic and nonperiodic fluctuations taking place in real life. A closer look at the applied social networks research also reveals some related approaches, which deal, in one way or another, with simulations of the field-like information spreading in social networks. For instance, common behaviours spread through dynamic social networks (Zhang and Wu 2011), the spread of behaviour in online social networks (Centola 2010), urban traffic control with coordinating fields (Camurri et al. 2007), mining social networks using wave propagation (Wang et al. 2012), network models of the diffusion of innovations (Valente 1996), oscillations-based simulation of complex social systems (Plikynas 2010; Plikynas et al. 2014), etc.

On the other hand, some perspicacious, biologically-inspired simulation approaches have emerged in the areas of computational (artificial) intelligence, agent-based and multi-agent systems research (Nagpal and Mamei 2004; Raudys 2004). In turn, these advances have laid the foundations for simulation methods oriented towards intelligent, ubiquitous, pervasive, amorphous, organic computing (Poslad 2009; Servat and Drogoul 2002) and field-based coordination research (Bandini et al. 2006; Camurri et al. 2007; De Paoli and Vizzari, 2003; Mamei and Zambonelli 2006).

In this regard, the major insights of this research are derived from the novel Oscillation-Based Multi-Agent System (OSIMAS) social simulation paradigm, which links emerging research domains via coherent oscillation-based representations of the individual agents and society (as a coherent collective agent system) states as well (Plikynas 2016).

The current peer-to-peer based ABS and MAS direct communication approaches have been unable to incorporate this huge amount of indirect (contextual) information. This is due to the associated complexity and intangibility of the informal information, and the lack of a foundational theory that could create a conceptual framework for the incorporation of implicit information in a more natural way. Thus, there is a need to expand the prevailing ABS/MAS conceptual frameworks in such a way that nonlocal (contextual) interaction and the exchange of information could be incorporated. It

seems plausible that we could introduce local MAS_L and nonlocal MAS_N, layers of selforganization in the prospective ABS/MAS simulation platforms

$$MAS = (1 - \eta)MAS_L + \eta MAS_N, \quad (1)$$

where $0 \leq \eta \geq 1$ denotes the degree of nonlocality:
$\eta \Rightarrow 0$, then MAS = MAS_L,
$\eta \Rightarrow 1$, then MAS = MAS_N.

In this way, we expand the concept of the ABS/MAS by adding nonlocal levels of self-organization. Starting with 0, self-organization could be observed (i) at the local single agent level, (ii) on the intermediate scale $0 << 1$, it could be observed in coherent groups and organizations of agents, and (iii) on the global (social continuum) scale (1), it could be observed in large, coherent, societies of agents. It naturally follows from some real life observations, e.g. agents interact locally (interchanging information with neighbours), but are also affected by the nonlocal states of the whole system (e.g. traditions, cultures, fashions, national mentalities, political situations, economical/financial situations, etc.). Here the term 'nonlocality', which we borrowed from quantum physics, could have many social interpretations, but we prefer to understand it as Jung's archetypes of the collective unconscious, which can be thought of as laws of nature in terms of structures of consciousness (Laszlo 1995).

Thus, below following the OSIMAS paradigm and scheme of conceptual model design (see Fig. 2), there are explained some basic principles of social capital sharing through cultural participation. We start from the proposition that order in social systems can be interpreted in terms of social coherence happening through connections, interactions, and communications, which are taking place between individuals (simulated as agents) (Plikynas 2016). For that matter, semiospheres act as coded systems of communication and cultural events act as broadcasted content itself. In this regard, cultural events are interpreted as a form of formative communication, which is capable of influencing simulated agents' behavioral and communication patterns, and correspondingly their social capital too.

The second proposition is to assume that the relation between the flow of cultural events and their impact on the individual and collective social capital as well is too complicated for the top-down analytical description. Therefore, simple agent-based simulation models can be applied for the bottom-up modeling and investigation of emergent and complex social phenomena.

The third proposition concerns a novel (interdisciplinary) way to model (i) cultural information broadcasting, (ii) agents' communication mechanism, and (iii) the agents themselves. In short, we propose to adapt some well-known methods from physics, i.e., coherent oscillating systems approach.

The central idea is about modeling societies as opened semi-coupled systems of agents. Putting mathematical notations aside, an adaptation of the modeling principles from open physical systems of semi-coupled oscillators can be adapted. That is, following our previous research and well-known Axelrod approach (Axelrod 1997), we interpret agents' neighborhood interactions as semi-coupled oscillators' interactions, where agents are represented as a unique spectral composition of oscillations.

Oscillations' interference mechanism can be applied to model such interactions (Plikynas et al. 2015).

Following this line of thought, cultural events can also be modeled as excitatory energy triggers of oscillatory nature. In the long run, such external triggers can influence the coherence level of the system of semi-coupled agents (oscillators). Cultural excitatory triggers can be periodic or aperiodic (chaotic). Different types of cultural events could be represented using different harmonic frequencies. For instance, in our case, we use three types of events - high culture, popular culture, and sport. The same recurrent type of events can be differentiated using various amplitudes and phases.

Agents' neighborhood interactions and broadcasted cultural events impact - as communication processes - employ encoded semiospheric messaging (see the previous chapter).[1] Events' impact to the system of agents can be modeled as inversely proportional or, e.g., inversely proportional to the square of the distance between the event and an agent in Euclidean physical or social capital space (Plikynas et al. 2019).

In summary, there are three major modules involved: (1) oscillating agent model (OAM), which encodes essential agents' properties in spectral terms,[2] (2) wavelike interaction mechanism (WIM), which encodes rules for interaction between agents and between agents with broadcasted cultural events, and above all, there is a pervasive information field (PIF), which serves as a background medium (space web), where all communication is taking place, and information is stored, see Fig. 3.[3] Such parameterization setup is flexible and robust to represent basic properties of agents', their mutual interactions and broadcasted cultural events impact.

Hence, agents' communication in technical terms is realized via a universal medium, i.e., PIF, and is managed by the wave-like interaction mechanism (WIM). We envisage that oscillating agents can be integrated into a common PIF spectrum as individual sets of oscillation bands, which can be described by the oscillating agent model (OAM). This latter model realizes the production rules for the transformation of

[1] In semiosphere, the interaction between an agent and broadcasted cultural event leads to a small change of the agent's social capital, see Fig. 2. The same is true for the agents' mutual interactions.

[2] All time dependant state functions of agents' can be mapped to the frequency domain. An agent becomes represented in terms of a unique composition of vibrations (spectra). Instead of time dependant functions we are operating with spectra now. For transition we can employed the Fourier transform, but we may also use some other transformations like Gabor and wavelet, which can be employed too (Benenson et al. 2006).

[3] The study of coordinated models goes beyond computer science in that evolutionary computation, behavioral sciences, social sciences, business management, artificial intelligence, and logistics also somewhat strictly deal with how social agents can properly coordinate with each other and emerge as globally coherent behaviors from local interactions. To the author's knowledge, the close match to the proposed idea is explored by Mamei and Zambonelli in their study "Field-based coordination for pervasive multi-agent systems" (Mamei and Zambonelli 2006). They have been trying to achieve coordination for multi robotic applications by means of the PIF (pervasive information field) approach. This is an example of how engineers are starting to understand that, to construct self-organizing and adaptive systems, it may be more appropriate to focus on the engineering of proper interaction mechanisms for components of the system rather than on the engineering of their overall system architecture.

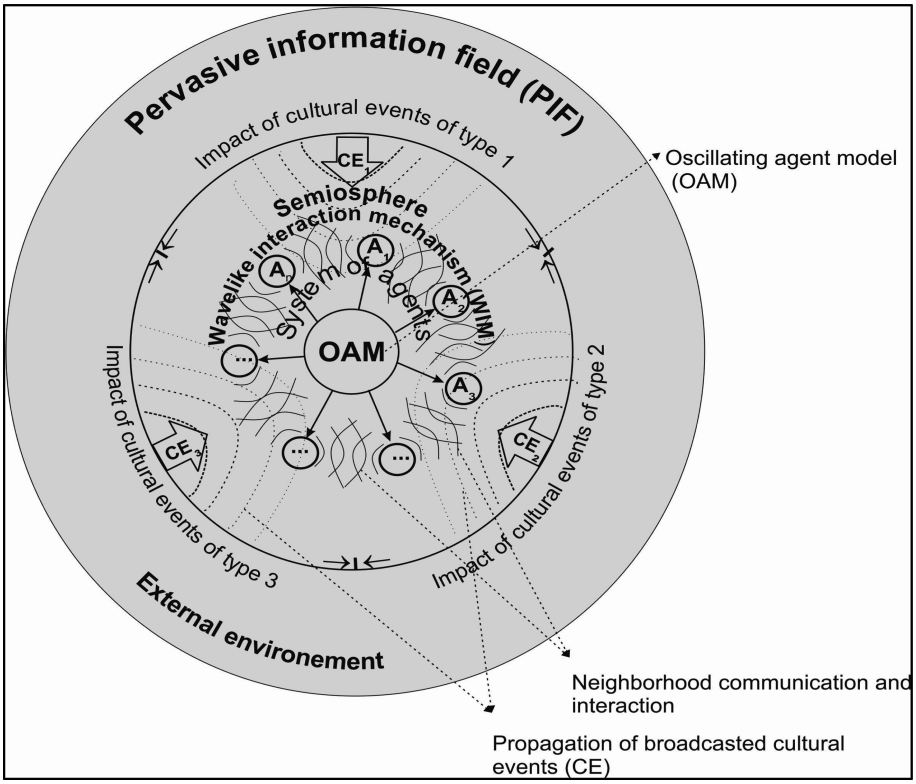

Fig. 3. Sharing of social capital through neighborhood interaction and cultural events impact in the framework of oscillatory paradigm (events and agents emit their characteristic oscillating bands), which is composed of three major modules: oscillating agent model (OAM), wavelike interaction mechanism (WIM), and pervasive information field (PIF). OAM produces a set of oscillating agents {An}, which compose agent-based simulation system. Three investigated types of cultural events (CE) appear in the allotted zones.

internal energy (a set of natural oscillations), which can be defined as a priori or induced from the agents' behavioral strategy.

Two neighboring agents interact if their natural oscillating frequencies and phases coincide. Such interfering interaction can be described using the resonance principle. Admittedly, the resonance increases the oscillating amplitude, i.e., energy, which can be arbitrary transferred to either agent. Such energy sharing can be used to encode social capital sharing. However, the main task of such modeling - to choose the logic for attribution and dynamics of natural frequencies and phases for the agents' population. This task determines the rules of the model and final simulation results (Plikynas 2016).

Members of society (as homeostatic agents) search for ways to sustain and increase self-organized order by increasing internal negentropy. Coordination between agents can be realized through coherent convergence, i.e., the synchronization of oscillation

phases. Such social binding involves the synchronous oscillations of agents as self-organized oscillating processes. In this way, having a proper setup, coherent social processes can be reduced to the oscillatory representations in the chosen semiosphere. The semiosphere acts as a mechanism for both – absorption and accelerating of mentioned processes, i.e. the relative boundary of semiosphere works as a filter that passes much more information about its 'own' cultural events and rejects most of the information about 'strange' (other semiospheres) cultural events and the information about 'own' cultural events in a particular semiosfphere spreads faster and more effectively than information about 'strange' cultural events.

5 Conclusions and Discussion

After the review of related literature, we found an evident lack of systematic conceptual models and consequently, quantitative approaches dealing with the relationship between cultural participation and social capital. Investigation revealed that there are very few research papers dealing with quantitative modeling or agent-based simulations in this research domain. It can be associated with the complexity, lack of fundamental understanding, and lack of proper quantitative approaches. Regarding the latter issue, difficulties stem from the drawback of (i) suitable quantification methods, (ii) meaningful measuring metrics, and (iii) causal relationship between cultural participation and social capital.

Therefore, this paper is dedicated for the introduction to the novel conceptual framework in this research domain. It gives not only better understanding of the social impact of dynamical cultural processes on the individual and society levels but also provides some nontraditional insights and tools for the quantitative metrics and bottom-up agent-based modeling.

In this regard, the paper proposes a joint framework of two mutually well-matching theories, i.e., semiosphere theory, initially developed by Yuri Lotman and (Lotman 2001) and pervasive information field (PIF) stemming from OSIMAS (an oscillations-based multi-agent system) paradigm proposed by Darius Plikynas (Plikynas 2016). The interoperability between semiosphere and PIF was investigated and six basic propositions were formulated.

Next, we investigate sharing principles of social capital in the framework of a coherent oscillatory paradigm. A closer look at the applied social networks research also revealed some related approaches, which deal, in one way or another, with simulations of the field-like information spreading in social networks. However, the significant insights of this research are derived from the novel Oscillation-Based Multi-Agent System (OSIMAS) social simulation paradigm, which links emerging research domains via coherent oscillation-based representations of the individual agents and society (as a coherent collective agent system) states as well (Plikynas 2016).

We propose a novel (interdisciplinary) way to model (i) cultural information broadcasting, (ii) agents' communication mechanism, and (iii) the agents themselves. In short, we propose to adapt some well-known methods from physics, i.e., coherent oscillating systems approach. The central idea is about modeling societies as opened semi-coupled systems of agents. We briefly explain how modeling principles from

open physical systems of semi-coupled oscillators can be adapted. That is, following our previous research and well-known Axelrod approach (Axelrod 1997), we interpret agents' neighborhood interactions as semi-coupled oscillators' interactions, where agents are represented as a unique spectral composition of oscillations. Oscillations' interference mechanism can be applied to model such interactions (Plikynas et al. 2015). Following this line of thought, cultural events can also be modeled as excitatory energy triggers of oscillatory nature. In the long run, such external triggers can influence the coherence level of the system of semi-coupled agents (oscillators).

In summary, there are three basic modules involved: (1) oscillating agent model (OAM), which encodes essential agents' properties in spectral terms, (2) wavelike interaction mechanism (WIM), which encodes rules for interaction between agents and between agents with broadcasted cultural events, and 3) a pervasive information field (PIF), which serves as a background medium (space web), where all communication is taking place, and information is stored.

Such modeling setup is flexible and robust enough to represent basic properties of agents', their mutual interactions, and broadcasted cultural events impact. It enables expansion of the prevailing ABS/MAS conceptual frameworks in such a way that nonlocal (contextual) interaction and the exchange of broadcasted information could be incorporated naturally.

Just like most studies in the complex social research domain, the proposed conceptual framework requires a thorough further investigation. Additional ABM/MAS based simulation research is necessary to examine, in detail, the issues and criteria that will help to identify the appropriate semiosphere and OAM-WIM-PIF parameter setup to get closer to the simulation of the real-life empirical observations.

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