Modelling the Index of Collective Intelligence in Online Community Projects

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Abstract: The recent successes of systems like Google, Wikipedia or InnoCentive suggest that individuals and groups can more effectively create valuable intellectual products by acting on the basis of a collective intelligence (CI) (Malone et al, 2012). The subject of our research paper is online community projects which include collective decision making tools and innovation mechanisms allowing and encouraging individual and team creativity, entrepreneurship, online collaboration, new forms of self-regulation and self-governance by considering these projects as being catalyst for emergence of CI. Our quantitative research explored the extent and major trends of the engagement and participation of Lithuanian society in online community projects and have proved the necessity to search for tools fostering civic engagement and collective decision making. The objective of our research project is the intention to propose managerial, social and legal measures for the stimulation of the process. The first step by implementing this ambitious task is to define a set of criteria for measuring Collective intelligence in networked platforms. In this paper we are introducing the theoretical model for CI Potential Index for a scientific discussion. The methodology will allow to identify and analyze conditions that lead online communities to become more collective intelligent: inclusive, reflective and safe. The CI Potential Index will show the state and dynamics of the CI according to changes of various internal and external parameters. The data necessary for the identification of the CI Potential Index dimensions were collected during the quantitative and qualitative research and will be revised during the scientific experiment. A longitudinal observation of a number of networked platforms will be undertaken to measure agreed representative parameters.

Keywords: collective intelligence, decision making, online communities

1. Introduction

Scientific society argues that in general human groups demonstrate higher capabilities of information-processing and problem solving than an individual (Heylighen, 1999; Luo et al., 2009). The term "wisdom of crowds" was coined by Surowiecki (2005) and it describes a phenomenon where, "under certain conditions, large groups can achieve better results than any single individual in the group". Surowiecki (2005) made an extensive research on collective judgment and intuition of crowd. Based on empirical investigation author argues that "under the right circumstances, groups are remarkably intelligent, and are often smarter than the smartest people in them". "Collective intelligence is the general ability of a group to perform a wide variety of tasks" (Woolley et al. 2010). Intelligence in groups emerges when each individual assesses overall situation and acts correspondingly to achieve the overall goal (Leimester, 2010). Wise et al (2010) empirically investigated this pronouncement and proved that groups leveraging CI can outperform individual experts in a controlled set. Both a simulation model (Hong, Page, 2004) and an experiment with humans (Krause et al, 2011) have shown that under certain conditions groups of divergent problem-solvers can outperform groups of high-ability problem solvers. Furthermore, the best problem solvers were biased in their estimations, while the group, as a whole, was accurate (Krause et al, 2011). Hong, Page (2007) proved using mathematical modelling and case studies that "power of diversity creates better groups, firms, schools and societies (The Diversity Theorem)".

As mentioned before, CI exist generally without the use of technology. "It is a conceptualization of a fundamental human tendency to do seemingly intelligent things in a Collective manner," as defined by Malone et al (2009). With advancements of Web based technologies, "the way in which CI is utilized and leveraged has been fundamentally altered" (Wise, 2012). "In the same way that multinational corporations have become far more efficient by outsourcing work to other countries and rob sourcing work to intelligent, interconnected machines, **we as individuals are becoming far more productive by instantly connecting our thoughts** to computers, servers and data bases all over the world" (Gore, 2013). The new channels of communication and information flow enable new possibilities to be involved in collaborative activities for broader groups of people in shorter amounts of time. "Complex interactions of millions of users manifest themselves as a probabilistic phenomenon in a way that has even been compared to the workings of a brain" (Pomerlau, 2009). "They go beyond the 'one-to many' strategies of the broadcast age, to enable the 'many-to-many and the 'many-to-one' strategies of the Web 2.0 age" (MIT Center for Collective Intelligence, 2010).

Any situation "where large enough groups of people gather, act individually but also share some common community goals could potentially be – through the proper use of technology – transformed into a **Collective intelligence system**" (Lykourentzou et al, 2011). From open-source software development communities, to competitive platforms used by companies to extract possible solutions for various R&D problems one can notice significant variance of CI systems in nature (Lykourentzou et al, 2011). The concept of collective intelligence is closely related with many **other existing conceptualizations** i.e. **Open Innovation** (Chesbrough, 2003); **Crowdsourcing** (Howe, 2008); **Wisdom of Crowds** (Surowiecki, 2004); **Wikinomics** and **Mass collaboration** (Tapscott and Williams, 2006); and **Service Dominant Logic** (Vargo et al., 2008). These paradigms take advantage of the potential of online media "to leverage connectivity, responsiveness, creativity and innovation, thus developing value co-creation potential for the stakeholders" (Wise, 2014).

Volumes of literature published display the growing activity and enthusiasm when research CI. However, current fragmented efforts (e.g. Luo et al. 2009, Gan et al, 2007, Malone et al, 2010) do not provide generally accepted framework for studying collective intelligence in human behavior due to complex nature of studied object. This makes it impossible to assess current state of knowledge and link various disciplines together (Salminen, 2012). Many authors have created redundant or conflicting definitions (e.g. "global brain", "team intelligence", "collective mind", "communal intelligence", "organizational learning", etc.) and there different abstraction levels in the discussion about the phenomenon (Salminen, 2012). However, each attempt to systemize knowledge and conceptualize phenomenon leads to promising future of the CI purposeful application and effective employment in society life.

The subject of our research paper are online community projects which include collective decision making tools and innovation mechanisms allowing and encouraging individual and team creativity, entrepreneurship, online collaboration, new forms of self-regulation and self-governance by considering these projects as being catalyst for emergence of CI. In this paper we are introducing the theoretical model for CI Potential Index for a scientific discussion. The methodology will allow to identify and analyze conditions that lead communities to become more collective intelligent: inclusive, reflective and safe.

2. Defining criteria for collective intelligence

Our first step in this paper is the intent to propose a set of criteria for measuring Collective intelligence in CI systems (online community projects). According Luo et al (2009) online communities, although different in functionality, "**seem to share some basic common attributes and provide the potential for the design o**f a general methodology that will allow the systematic development and optimization of CI systems." In this chapter, we identify prevalent features and major obstacles in the construction of generic Collective intelligence system model.

Together with studies focusing on issues solved through the application of CI-inspired techniques, a number of research efforts, contribute to modelling the functionality of CI systems. An attempt to identify the most basic characteristics of CI systems was made by Lykourentzou (2011). Their conceptual model contains a static or structural view and a dynamic view and includes three specific values: '**the set of possible individual user actions', 'the system state, and the community' and 'individual objectives'.** The set of individual actions influences the system state, defined as the minimal set of variables that may describe the important aspects of system. The community objective refers to the benefit that the community aims at through the use of the CI system, while the individual objectives refer to the benefit that each user foresees in the use of this system. In addition 3 important functions necessary for the modelling of the CI system are described: **Expected user action function, Future system state function, and Objective function (**Lykourentzou, 2011)**.** According Luo et al (2009) the key feature of 'community intelligence' (the authors use this definition for describing collective intelligence of online communities) is that it is **self-organizing and 'emergent**'. Community members develop their individual cognitive processes and transmit them to other members. The main difference of CI from team or organisation intelligence is lack of "swarm effect" due to small number of individuals involved. Massive participants' inclusion into interactions ensure emergence of greater intellectual capabilities. Online communities tend to be more dynamic and open a feature that sets them apart from businesses, government bodies and other institutional organizations. Because of flexible and vague boundaries of online communities, people have more freedom of joining and leaving as opposed to fixed boundaries of institutional organizations.

The Structural Model of Community Intelligence (Luo et al, 2009) explains how the community level intelligence may generate from the knowledge-related activities of the participants or the community members. The community should contain a **memory system that stores information and knowledge, the capability of 'intelligent' problem-solving, and** should commonly exhibit higher-level intelligent capability than any community member. Rodriguez (2005) suggested paralleling CI to individual intelligence and performance of human brain as a strategy of CI modelling. Basing its findings on ideas from neuroscience field, author describes the way that "human brain finds solutions to problems that it has not yet encountered, by storing the already seen experiences and solutions to lower levels of its cortex, and then by grouping similar events to a more abstract higher-level of the cortex" (Rodrigez, 2005). Hence, human brain uses the higher levels of its cortex to perform a pattern-matching procedure in order to solve problems. Rodriguez (2005) offers to model collective intelligence in a similar manner using solutions suggested by community users who can access the generic higher-level of the CI hyper-cortex to find problem solutions. The researchers' team at Massachusetts Institute of Technology "MIT Center for Collective Intelligence" proposed conceptual framework of **Collective Intelligence Genoma** where main structure elements are identified as "Staffing" (Who is performing the task?), "Incentives" (Why are they doing it?), "Goal" (What is being accomplished?) and "Structure/Process" (How is it being done?) (Malone, Laubacher, Dellarocas, 2010). **Staffing** refers to characterization of the group that is involved in Collective Intelligence emergence, mainly about its structure and relationship between structure elements. The researchers distinguish to types of groups: **crowd,** where anyone in the large group can take activities, without being assigned by someone in a position of authority; and the **hierarchy**, group of individuals where someone in authority assigns for other participants to perform the task.

According Lykourentzou et al (2011) CI systems may be divided into two categories: **passive and active systems.** In case of passive CI systems, individuals undertake same actions as they would normally do without the systems' presence. The only difference is that technological applications allow to observe the behavior of the crowd based community and then modelled into a **passive CI system** that will give information on facilitation of individual and community goals (for example transport network coordination). In type of **active CI systems**, crowd behavior does not pre-exist but it is created and coordinated through specific system requests. It can be split into the following categories: **collaborative, competitive, hybrid.** Related to this Levine, Prietula (2014) argue that "a group's cooperative outcomes can be remarkably well predicted if one knows its type composition." The general human population has been estimated to consist of three cooperative types: ***Cooperators*** (13% of the general population), ***Reciprocators*** (63%), and ***Free Riders*** (20%). (The remaining 4% are too inconsistent to be categorized). Tinati et al (2014) discovered that 'active' users produce 70% of the content and assume the role of the 'core community'. "These results reflect other peer-production systems like Wikipedia; despite obtaining a large user-base, it is the activities of only a relatively small collection of users that produce content" (Tinati et al, 2014). Majchrzak, Malhotra (2013) further defined 3 obstacles viable for crowd collaboration: 'tension between competition and collaboration', 'insufficient time-spent by individuals', and 'lack of condition for creative abrasions'. Kittur et al (2013) identified "many technical aspects where research is still to be done, such as workflow and hierarchy design, the collaboration between artificial intelligence and crowd etc."

The Internet has reputation as transparency-boosting medium, but it does not necessarily work as prescription for smart reform which requires a thorough empirical investigation into the world of politics (Morozov, 2013).Theoretical and empirical study of Dabbish et al (2014) suggest that "providing transparency of actions on shared artifacts supports cooperative work" and propose variety of ways that transparency can support innovation, knowledge sharing, and community building. However, Morozov (2013) is convinced, that information should be distributed in full **awareness of the social and cultural complexity** of the institutional environment in which it is gathered. Close related to transparency is problem of **independence.** Violations of the independence condition might decrease the accuracy of the crowd (the promotion of the idea to friend or relatives, also down voting, where some users create multiple accounts to give high scores to their own designs and low scores for everyone else) (Salminen, 2014). Previous studies (Mavrodiev et al, 2012, Lorenz et al. 2011) have reported impaired independence of thought by social influences in crowdsourcing platforms.

According to Boder (2006) Collective **Intelligence emergence** is composed of three building blocks: **competencies development, goal development, and mechanics development**. Each block draws from pre-existing knowledge and is developed in order to achieve Collective Intelligence. Schut (2010) distinguishes **enabling and defining properties** of CI. **The existence of enabling properties such as adaptivity, interaction and rules executed at a local level make it possible for collective intelligence to emerge from a system** (''how do we build CI systems?"). The defining ones are those that if you observe these properties, the system is a CI one

(''how can we better understand CI as observed in nature, including human nature?"). If the system can be observed to show a distinction between global and local, randomness, emergence, redundancy and robustness, the system is a collective intelligence one. The former are on the local (agent) level, whereas the latter are on the global (system) level (Schut, 2010). Face-to-face group processes in organizations often lead to polarization when faced with social influences (Janis 1982, Isenberg 1986). Independent expression can also be damaged by external pressures such as managerial influence and intolerance to mistakes (Zhou, Fink, 2003; Michailova, Husted, 2003). According Norvaišas (2011), in order to eliminate negative social, psychological and other subjective impacts (subjectivity), we must guarantee anonymity of participants in online communities.

The identified criteria will be used as a theoretical foundation for conceptual framework for assessing CI potential in the next chapter.

3. Conceptual framework for collective intelligence (CI) potential index

Our proposed **CI Potential Index** modelling approach focuses on facilitating framework to evaluate online community projects and identify cases that can be potentially transformed into effective CI systems, as well as on "enabling developers to design, implement and optimize CI systems so that the community and individual benefits will be maximized" (Lykourentzou et al, 2011). The CI index will show the conditions, state and dynamics of the potential CI according to changes of various internal and external parameters (Regional Social Innovation Index, 2013). Virtual research environment with required software for scientific research activities will be created to be able to develop the proposed methodology and to apply **CI Monitoring Technique** for the future research activities.

The data necessary for empirical validation of the CI Potential Index parameters were collected during the theoretical analysis of scientific sources, quantitative and qualitative research, was revised during the scientific experiment. During the qualitative research 20 in-depth interviews with the participants of virtual community projects were completed and another 10 interviews with the initiators/developers of online community projects supplemented the empirical research. Qualitative research was conducted by using a semi-structured questionnaire. The aim of the interviews was to gain a deeper and broader understanding of the external and internal factors promoting or hindering the formation of collective intelligence. The quantitative research was undertaken by respecting general rules of a random stratification sample and the specifics related to the participation in the process of collective intelligence emergence. Sample (N=1022) included 478 males and 544 females aged 15-74 in all districts (urban and rural areas) of Lithuania, which guarantees a statistically reliable representation (with the confidence level of 95%) of the Lithuanian population. Public opinion survey was carried out using the method of direct interview at respondents' houses using computerized and standardized questionnaires. Interviewed respondents represented the overall Lithuanian population by the major socio-demographic characteristics (using stratified random sampling). After collecting the survey data, statistical study was carried out using SPSS for Windows. Statistical relationships between attributes were calculated by using a chi-square ($\chi 2$) tests. Significance level of $p < 0.05$ was chosen to calculate statistical reliability. We also have adapted the theoretical insights and empirical evidence from Sinnergiak Social innovation researchers group**,** developing Resindex (Regional Social Innovation Index, 2013). Their experience was valuable example for conzeptual construction of the CI Potential Index and the CI Index has been designed around three indices, which are defined by different dimensions.

The CI Index methodology will allow to identify and analyze conditions that lead communities to become more intelligent. Theoretical insights and our empirical research results reveal that at the current knowledge level capacity for developing competencies, emergence and social maturity are important features of the CI systems. Measuring them could be useful in predicting the global performance of the system as a whole (see Figure 1):

The conslusions of our theoretical and empirical analysis (Skarzauskiene et al, 2014) suggest that to explore potential of CI it is necessary to to differentiate between three dimenssions: **capacity level**, related to the set of possible individual user actions (Lykourentzou, 2011), interactions of massive participants (Luo et al, 2009), competencies development (Boder, 2006); **emergence level,** related to the system state (Lykourentzou, 2011), self-organizing and "emergent", "swarm effect" (Luo et al, 2009), mechanics development (Boder, 2006) and **social maturity level,** based on the community and individual objectives **(**Lykourentzou, 2011)**,** goal development (Boder, 2006) etc. During our empirical research we identified various dimensions which cover different aspects of each of the SubIndex and created a different group of indicators to measure each dimension,

for example, the *Capacity for Creativity* includes 2 dimensions: *Degree in diversity in the source of ideas* and *Degree of diversity in engagement forms.* Each dimension reflects from grouping different indicators (**organizational and behavioral level**) based on questions about platform structure and activities (Web analytics) (Pitrenaite-Zileniene, Maciuliene, 2014). The second group of indicators (**technological level**) are grouped around technological parameters of the platform itself: expansion, risk and value related social technologies. It should be noted that in this paper we offer theoretical framework of Potential CI Index for scientific discussion. **Our next step is validation of the proposed model on the basis of a longitudinal observation** of number of networked platforms to measure agreed representative parameters. The **systems dynamic model of CI** was developed to test relationships between different CI dimensions will be created in the framework of future research activities.

CAPACITY INDEX	INTERPRETATION *MACRO LEVEL*	INDICATOR
CAPACITY FOR CREATIVITY	Identifies dynamism and openness of community. The more varied structure of participants, the higher capacity for creativity	Degree of diversity in the source of ideas Degree of diversity in engagement forms
CAPACITY FOR AGGREGATING AND CREATING KNOWLEDGE	Identifies level of capacity for creating collective knowledge among community members	Degree of interdependence Degree of adequate supply of "Critical mass" ("swarm effect")
CAPACITY FOR DECISION MAKING AND PROBLEM SOLVING	Identifies level of competencies for independent decision making and problem solving	Degree of decentralization Efficiency of problem solving Degree of independence
EMERGENCE INDEX	INTERPRETATION *EMERGENCE LEVEL*	INDICATOR
POTENTIAL FOR SELF-ORGANIZATION	Identifies the degree of self-organization to reach community task	Adequacy in form of self-organization to community task Degree of development of transparent structure and culture
INTENSITY OF EMERGENCE	Identifies the intensity of emergence of new quality based on distributed memory and shared knowledge ("wisdom of crowd" effect)	Degree of development of new qualities in form of ideas, activities, structured opinions, competencies etc. based on distributed memory system (Web intelligence)
POTENTIAL FOR ADAPTIVITY	Identifies degree of ability to adapt changes in socio-cultural context	Adequacy to socio-cultural context (local, national, global) Degree of development of improvements and learning processes within the community Development of life-long learning
SOCIAL MATURITY INDEX	INTERPRETATION *MICRO LEVEL*	INDICATOR
MATURITY OF SOCIAL IMPACT *BEHAVIOURAL*	Identifies extent of civic engagement and impact on public opinion	Degree of civic engagement Degree of sustainability
MATURITY OF SOCIAL MOTIVATION *PSYCHOLOGICAL*	Identifies maturity of motivation to deal with societal challenges	Level of maturity of social motivation of community Level of social sensitivity of community members
MATURITY OF SOCIAL ORIENTATION *COGNITIVE*	Identifies maturity of monitoring (identification) social matters and value of generated content for society	Level of maturity of reaction to social issues Degree of diversity in cooperating partners and financing Level of maturity of generated content

Figure 1: The potential collective intelligence index

4. Conclusions

We **define collective intelligence systems** as large groups of individuals acting collectively through use of technology and sharing some common community goal in this paper. Based on our theoretical and empirical research results we attempt to define characteristics shared by various CI systems with the goal to design **the CI Monitoring Technique**. The modeling approach is based on CI system functionality and identifies the basic issues related CI emergence. The CI Potential Index modelling is expected to facilitate IT developers, policy makers, initiators of community projects in recognition of potential to become a CI system and maximize benefits individuals and community as a whole will gain.

Developing active and social oriented online community including maximum number of CI components requires not only innovative technological solutions but also efficient managerial competencies. Higher number and quality of required components ensures better conditions for CI emergence and consequently more possibilities for online community performance. Evaluation of existing collaborative platforms provided insights for creation of new IT based tool stimulating self-organization, collective decision making, collective learning etc. Exploring the potential of collective intelligence could help organizations become more innovative and help communities tackle important issues adequately. By creating new global products or solving societal challenges innovative organizations use social technologies for increasing performance, but **without scientific reasoning** they often choose not adequate tools or methods and don`t create expected value and sustainability.

CI development field requires deeper research from academic and practical angle. It would be important not only to identify the assumptions affecting developing of CI, but also **to predict possible development scenarios** and to define risk areas. Nonetheless, considering the interdisciplinary nature of CI, future research efforts could concentrate on combination of proposed methodology with the compatible findings of different research fields e.g. computer science, network management, social science, biology and cognitive science. This could lead to broadening of our CI understanding and would provide thorough view on the phenomena.

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