New Approaches to the Improvement of Coordination Mechanisms

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Abstract

The intensity and scale of communication between people, which have grown significantly over the past three decades, have not yet led to comparable improvements in the coordination of the activities of socioeconomic agents. One of the reasons is the lack of a full-fledged digital transformation of coordination mechanisms. Therefore, an urgent scientific task is to determine methodological approaches for the full digitalization of coordination processes. Cognitive sciences offer a fundamental description of the processes of socioeconomic coordination in the form of a shared mental model of participants in joint activities. Based on this, the concept of coordinating the activity of agents, which is the basis of all coordination processes, is defined. This approach made it possible to identify and analyze the main elements of the fundamental process of coordinating activities, as well as to determine the opportunities for its digitalization. This paper discusses the opportunity to create a unified coordination mechanism based on computer technologies, which, on the one hand, could replace the traditional market and hierarchical mechanisms, and on the other hand, could be used to coordinate all types of joint activities, including non-economic ones.

Keywords: coordination of activities; contextual changes; hierarchies; mental model; mechanism of coordination; digitalization

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Introduction

The key modern socioeconomic development analysis methods are associated with the concepts of complexity, capabilities, and knowledge (Metcalfe, Foster, 2004; Antonelli, 2011; Fagerberg, Srholec, 2008). These terms comprehensively describe management systems applied to coordinate the interactions of agents. In this context, developing socioeconomic coordination models complements the existing techniques, and thus becomes a relevant objective. The coordination process has a complex structure, and manifests in various forms including hybrid ones (Powell, 1991; Malone, Crowston, 1994; Dementiev et al., 2017). Accordingly, such mechanisms are defined in academic literature in various ways.[1] Digitalization inevitably affects the functioning of coordination mechanisms, and if properly managed, can significantly increase the effectiveness of agents' interactions, thus providing an additional impetus for economic development (Nielsen, Jordanoski, 2020). To achieve this, it is first of all necessary to understand how coordination works at a fundamental level and how it should be digitalized to obtain the desired positive effect.

A number of factors must be taken into account when planning coordination activities (CA): the common semantic environment which implies certain behavior rules and communication signals, data sharing options, prerequisites for the emergence of information images of the "partner family" members, conditions for finding collaboration options by testing the available possibilities based on individual and shared mental models, and criteria for making decisions about entering into a partnership.

At any given time, a certain number of options exist for each aspect. Their combinations determine the set of available CA configurations. Depending on the activity type, its context, and the number of partners involved, a scheme is chosen which provides maximum benefits for all participants. Most successful configurations created in particular areas are subsequently institutionalized in the form of general rules, which promotes their wide adoption. Thus, if the content of CA is known, their mechanisms can be improved upon by applying advanced information and communication technologies (ICT). Digitalization allows one to standardize certain CA elements, which partly smooths out the qualitative differences in relevant mechanisms (e.g., between market regulation and hierarchy). At the same time, flexibility in adapting CA to the actions of individual agents with the help of computer algorithms increases. It becomes possible to create a complex adaptive regulatory system, to replace multiple existing mechanisms with limited functionality.[2] This would allow for using resources more productively and enhancing economic and social effects.

Approaches to Coordination in the Economy

Activities are coordinated in various formats and their combinations, which determine the variety of coordination measures. An agreement on joint work can be reached through a direct exchange of information. However, communication is often indirect in nature: agents observe the behavior of other participants in the common environment and take it into account. Finally, following common behavior rules ensures the consistency of the steps taken, even in the absence of direct or indirect communications. Let us consider each format in more detail, with examples.[3]

Direct communication. The first approach views coordination as a result of direct dialogue between all participants in the process and their agreements. Such "orchestration" allows one to divide responsibilities in the best possible way, and make sure they are carried out in a clear sequence. Regular dialogue and iterative adjustments of the roles played allow the team to flexibly respond to changes in the environment. In the literature, this approach is often referred to as networking (in the "everyone with everyone" format) (Powell, 1991; Provan, Kenis, 2008). However, in our opinion the term "network" does not accurately reflect its specific features. Any kind of agreement is based on relationships which can be presented as a network of links. Trust is more important here: the participant's subjective assessment of the likelihood that their partners or the team will follow the agreed upon plan (Adler, 2001). Therefore, the term "agreement" would be more suitable to describe this type of communication.

Another direct coordination type is delegating the right to decide who should be responsible for what to the manager. In this case an agreement is reached over the course of employee-manager interaction in the format of hierarchical (administrative) communication (Malone, Crowston, 1994; Weigand et al., 2003). Currently the agreement and hierarchi-

[1] An overview of definitions of the "coordination" concept can be found in (Weigand et al., 2003).

[2] A similar idea was discussed in our previous work in the scope of analyzing the properties of a perfect mechanism for coordinating socioeconomic activities and the conditions for designing it (Parinov 2020).

[3] There are numerous studies devoted to other aspects of coordination, in particular those on economic and complex systems; their reviews are presented in (Vlasova, Molokova, 2019; Khodakov et al., 2014).

cal approaches are most often applied in combination (Powell, 1991; Malone, Crowston, 1994; Dementiev et al., 2017). For example, a member of a team of workers is given a job by the manager, and then the team members agree on the division of responsibilities. In turn, the managerial decision can also be made collectively (by a board of directors, etc.).

Indirect communication. Here we are talking about the interaction between agents who cannot or choose not to share information directly. They observe each other's activities in a common semantic field, including the internet environment. Traces of their activities (special markers, etc.) may contain detailed information for other agents' behavioral decisions. This format is often referred to as *stigmergy* (Elliott, 2006; Marsh, Onof, 2008; Elliott, 2016; Heylighen, 2016). A particularly bright example of coordination partly implemented through indirect communication is the interaction of market players in the context of trading and negotiating prices. Buying and selling operations leave a trail that affects the prices of goods, which in turn encourages further transactions (Heylighen, 2016). One of the motivators in this case is competition (Polterovich, 2018). Further on we will use the term "stigmergy" to refer to this format, and assume that market coordination is a hybrid approach which includes stigmergy, agreement, and hierarchical formats (Powell, 1991; Malone, Crowston, 1994; Dementiev et al., 2017).

Following the rules. Behavior rules, explicit and implicit norms, and generally accepted cultural attitudes allows "network" participants to act smoothly even without communicating with one another. This is the case when precedent actions are taken into account by other agents by default, e.g., when they use public benefits.

All of the above approaches can be used in parallel or in combination. In practice, a complex multilayer system of various, qualitatively different coordination processes emerges.

Developing an Integrated Coordination Mechanism

The main problem a systemic study of diverse coordination formats faces is identifying the basic principles of this process, formulating them, and designing approaches to their analysis (Malone, Crowston, 1994). The existing theoretical models and methodological tools are not enough for solving this issue. A universal coordination mechanism must be developed, along with structured approaches to assessing the available alternatives and choosing among them (Crowston et al., 2015, p. 29). In our opinion, these objectives can be accomplished if we consider the coordination processes from the standpoint of specific actors' behavior, and on the basis of the latest cognitive sciences advances, in particular the mental model concept (Johnson-Laird, 1980; Mantzavinos et al., 2004; Badke-Schaub et al., 2007).

A mental model is defined as a mechanism for describing the system, its purpose, forms, and operation, assessing its current state, and forecasting future ones (Mathieu et al., 2000). The "team mental model" concept reflects the implicit coordination characteristics of effective teams and expands the understanding of how they operate in complex, uncertain, and rapidly changing situations (Mohammed et al., 2010). The prerequisites for identifying basic principles and developing a comprehensive definition of coordination are built on the fact that in the mind of an individual agent, all the diversity of its forms merges into a single system. This synthesis is supported by a mental model, since by definition it embraces all the collaborative activities the participant is involved in, and the perceived interdependencies between them. In the understanding of an individual, all coordination processes are combined by a certain specific CA, which allows the individual to build a mental model in their mind, containing information images of their counterparts' capabilities and intentions. The model allows one to calculate the interaction options and select the best one for the implementation (sometimes jointly with partners[4]). Due to the involvement of other players, coordination, along with the main activity, becomes a joint process for them, which takes several forms. Each participant accumulates data on the actions of other actors in the common environment, leading to the emergence of information images in their mind, which are updated as new information is received. The actual content of these ideas also depends on the effectiveness of other players' participation in the CA, whose images must be adapted to the specific features of a particular activity type. The effectiveness of coordination depends on the consistency of various information images, which must have certain common features for the same type of joint activity (Table 1).

Partners' information images become a part of the mental model of the context where the agent operates, along with other information related to his/her activities. They encode information about the dynamics of the business environment, strategies for responding to external changes, collective

[4] The processes of coordinating joint activities on the basis of agents' mental models described in this and the following sections are based on the system of hypotheses and their consequences presented in (Parinov, 2020, pp. 11–19).

Table 1. **Characteristics of Agents' Information Images, Collaboration Types**

Partnership type	Information images' characteristics
Agreement	Can realistically describe agents' status due to direct information sharing
Hierarchy	Contain agents' professional characteristics, describe their competencies and responsibilities
Market regulation	Agents' images are represented by the products and services they offer, the prices of which are adjusted by the interplay of supply and demand.
Following common rules	Not applicable, because no communication between agents takes place

Source: author.

goals, and participants' interdependence (Salas et al., 2005). As a result of agents' active interaction in creating and updating their individual mental models, a common configuration of joint activity naturally emerges (Badke-Schaub et al., 2007). By continuously sharing information in the "everyone with everyone" or "worker-manager" format, participants maintain in each other's minds an up-to-date understanding of both the current state of affairs and individual strategies, which allows for anticipating partners' actions and estimating the amount of resources needed to implement the plans (Mathieu et al., 2000). By developing a common mental model, team members can interpret information in the same way, share visions of the future, and identify causal relationships (Mohammed et al., 2010). As a result, each of them obtains a more complete picture of the environment they operate in, and of the changes occurring there. The team mental model "works" under a certain set of conditions, including mutual trust and "closed" communications (Salas et al., 2005). As was noted, an individual mental model allows the agent to analyze possible interaction options and choose the best one in each situation. In a team format, a mental model facilitates the analysis of group strategy options, the choice of the most suitable one for all team members, and its implementation.

An effective coordination "flow" largely stems from self-organizing processes inherent in complex systems, with their flexibility and a wide range of possibilities. Adjusting such processes requires taking several aspects described in Table 2 into account, and their combinations. By analyzing the changes in the external environment, status, and behavior of other players, the agent chooses the cooperation format and adjusts their strategy. Thus, the consistency of joint activities in a changing environment is achieved and maintained.

The practical application of each tool may vary depending on the context. Therefore, a variety of CA configurations inevitably arises, with different efficiencies. The efficiency depends on cooperation features (number of participants, activity type, and conditions). But whichever configuration is chosen, adjusting it to achieve the desired performance will take a significant amount of time. During that time unpredictable changes can occur in the external environment, leading to its transformation. We would like to reiterate that coordination processes cannot be updated without adjusting agents' mental models. If mental models' updating lags behind the rate of contextual changes, the models lose relevance, so the agreement process must be restarted.

Thus, two main factors of any CA configuration's effectiveness can be singled out: the speed of processing information available to players and the pace of external changes, which devalue the shared information. To discover and assess context changes, real-time data processing tools are needed, which increase one's chances to proactively adapt to changes. A configuration which allows one to

Table 2. **Tools to Support Coordination Processes**

Tool	Description
1. Signal system	Informs participants about ongoing processes, partners' resources and strategies, and general behaviour rules.
2. Communication format	Communications can be direct, indirect, or hybrid, depending on the specific activity, its context, and agents' natural abilities.
3. Participants' information images	Based on them, agents draw conclusions about each other's capabilities and intentions, and specific features of the communication environment. The dependence on other agents' images, accuracy, completeness, and relevance in reflecting the actual status of each of them are assessed.
4. Mental models	Applied to choose cooperation options. Individual models involve "calculating" the options in one's own mind, while team ones involve making decisions jointly with other players.

Source: author.

secure maximum advantages when taking into account the specifics of a particular activity type, available analytical resources, and the frequency of hard-to-predict changes seems to be optimal. If such optimized structures are constantly improved and follow uniform rules, over time they turn into an institutional basis for coordination processes, which reduces the costs of managing them.[5]

The above analysis suggest it would be possible to develop a universal approach merging various coordination formats. The structure described above is proposed as a basis, since it is present in all coordinated systems and can be applied in different configurations, depending on the nature of the main activity and the specific context.[6]

Thus, coordination processes (and their object, the core activity) involve the interaction between agents, and in their turn are subject to "orchestration" of a higher order.

Digitalization of Coordination Processes and its Effects

Digitalization transforms cooperation networks: a distributed global online system emerges, which significantly increases communication capabilities. Its further development requires the improvement of signal systems and behavior rules. A common virtual space will allow all agents, regardless of their geographical location, to make a full use of the coordination potential of advanced information and communication technologies. The digitization of information images implies the introduction of computer interfaces, by using which actors would present and update information about their intentions and options. Software tools are being improved upon to facilitate the processing, mutual synchronization, and distribution of these images among potential participants. The use of such tools increases the effectiveness of coordination, depending on the activity type and its context.

Software modification allows for fine-tuning digital images, while the complex task of coordination is adapted to the context of interaction between a particular group of agents. The interaction parameters are individually adjusted for each of them, depending on their resource potential and objectives. Computer monitoring of changes in the participants' information images and in the environment promptly sends signals about the emergence of obstacles hindering cooperation and the need to revise the latter's format. Thus, despite external changes, the "orchestration" of activities is dynamically maintained. Modern ICT allows one to integrate digital images into a unified system. On their basis, online services and simulation tools are created to evaluate possible partnership options. The range of criteria taken into account to choose effective cooperation modes expands significantly. Individual understanding of changes in the external environment, behavior, and status of other participants becomes deeper. The digitalization of CA simplifies cooperation to the maximum possible extent and increases its efficiency. All coordination mechanisms merge into a global simulation model that is interactive, realistic, and flexible. It involves both active agents and digital twins of the objects with which they interact. Various coordination types (agreement, hierarchy, stigmergy) acquire common features and can be used by teams regardless of the geographical location of their individual members. All processes are implemented through computer interfaces and algorithms, which, ceteris paribus, allow one to achieve higher coherence than under traditional approaches, accomplish more complex management objectives, and increase the maximum number of interaction participants. It becomes possible to change the coordination type or use complex hybrid combinations based on optimized recommendations made by the digital system.

Prerequisites for the Development of a Unified Coordination Mechanism

Profound integrated digitalization is gradually erasing the qualitative differences between the main coordination types, while their elements are being normalized. In the virtual environment, mental projections of agents' information images common for the agreement coordination format turn into digital objects alienated from the consciousness that created them. Software algorithms provide more advanced mechanisms for designing both individual and team mental models.

Modern ICTs allow for no less thorough direct communication than in a real environment, and given the absence of geographical limitations, the scope for sharing information significantly increases. In the case of market coordination, the digitization of images and activity traces eliminates the severe restrictions on the communication format typical for the stigmergic approach, since in a virtual environment it can easily be conducted both indirectly and directly.

[5] Traditional coordination mechanisms (agreement, hierarchy, and market ones) have developed in a similar way.

[6] For a detailed description of variations of the elements that make up the agreement, hierarchy, and market coordination formats, see (Parinov, 2021, pp. 13–19).

The digital transformation of information images allows agents to maintain as complete and up-to-date profiles in a common virtual space as possible, with the help of computer interfaces. Simplified versions of images can be automatically generated without agents' direct participation, depending on their role in the joint work.

The agents' CA is fully implemented in a shared virtual environment. Regardless of the cooperation format, it is regulated by a signal system and behavior rules uniform for all participants. Instead of direct and indirect communications in the traditional sense, actors use universal digital communication mechanisms to inform each other about their goals and capabilities. They create and update the most accurate digital images of themselves. The system algorithmically selects simplified versions of these images and possible connections between them (e.g. hierarchical ones) taking into account the type of joint activity. On this basis, a selection of the best cooperation options is generated, providing the highest combined benefits for all participants, which serves as a starting point for making decisions about individual contributions to a joint activity.

The digital transformation of CA leads to the unification and reduced diversity of its elements. As a result, different coordination formats, for example, agreement and stigmergy, converge in terms of the process content, which substantially simplifies the division of responsibilities between individual participants. The same steps become applicable for different types of cooperation, while in the pre-digital era applying them would require more complex, multidirectional efforts. Due to unification, agents' CA are reduced to collecting information in the virtual and real environments, updating their images, and choosing between the cooperation options offered by the system. All other elements are performed by computer software.

Taken together, the described processes open theoretical possibilities for designing and implementing an all-purpose global coordination mechanism, whose structural elements, properties, and principles have yet to be explored. The main benefits of adopting such a system are that instead of several disparate decisions, actors would have a unified adaptive mechanism which would increase the efficiency of activity coordination, including in the framework of the international division of labor. Software interfaces would play the role of institutional regulatory structures ensuring agents' compliance with specified rules, while also increasing the possibilities for their self-realization. All participants in the global economy would become their potential partners, while the strategic goals of and resources for joint activities would be presented in a more complete and qualitative manner.

The distributed global online system created as a result of the digitalization of CA will allow for coordinating any activity types. Interconnected, systemic coordination in the economy, science, sociopolitical, and educational spheres, and in the field of security among other areas will help accomplish individual goals through the adoption of a unified mechanism. Unique opportunities for realizing human potential to promote economic and social development are opening up.

Conclusion

The coordination of actions precedes obtaining results from any socioeconomic initiative, therefore, coordination mechanisms significantly affect such initiatives' outcomes. The former can be improved with digital technologies, the potential of which, however, has not yet been fully realized. Nevertheless, digitalization seems to be a necessary condition for further "upgrading" management systems.

This paper considers the possibility of creating a unified coordination mechanism as a logical consequence of digitalization and the unification of its elements. The development of such a toolkit will facilitate the coordination of various activity types, help better harmonize the interests of various groups, and more efficiently consolidate the efforts taken to meet global challenges.

Further research will allow one to assess the potential of advanced ICT in improving various types of partnerships and their performance. The versatility of CA as a tool for optimizing any cooperation format opens the possibility to develop a unified ICT-based coordination platform, adaptable to the particular conditions of agents' interactions. These research areas will provide a key to understanding the properties of the post-digital development stage of the economy and society, the most important aspect of which is the digital transformation of regulatory mechanisms and the associated social changes.

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