# The Prime Dynamics of System Computation

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**Abstract**

*From the perspective of socioculture cognitive system, the operation of teamwork is considered as a cognitive computation system essentially. Distributed and related person-technology interactions determine a cognitive system's properties. Each task performer proceeds organizing activities in order to do the tasks. In the organizing processes, he or she coordinates with other team performers, instruments, procedures, etc. Such interactions influence the teamwork system's cognitive properties and determine it's computational power, such as learning ability, flexibility, robustness, etc. That is to say the dynamic behaviors of group performance will depend on its underlying interactions. Based on Hutchins's research in 1996, this research develops a system dynamics model to explore and to understand the prime mechanism of teamwork. Fortunately, this paper provides a significant contribution on the process of team operations.*

## 1. Introduction

The strength of team work supports us to accomplish certain tasks by operations of distributed, parallel, interactive, and adaptive mechanisms (Hutchins, 1996; Williams, 1996; Ray D. and H. Bronstein, 1995). Today, teamwork is the major form for us to solve complex problems. However, a team's work does not equal to the sum of each member's work. Team is the emergence of its components and it has its own properties and characteristics. The operation of a team's work reveals specific dynamic and non-linear characteristics, which makes itself different from other teams. Teams are systems composed of individuals. Among these individuals, various kinds of interactions can be found. They are interactions between members, interactions between members and environments, and interactions between members and media, tools, and technologies. These interactions are substantial to a team's operation, therefore, it is important to understand its operating processes.

This paper intends to examine the adaptive mechanism of a self-directed team (Ray D. and H. Bronstein, 1995) from the cognition perspective. The mechanism represents actions and related information feedback between key elements. As the mechanism operates, multiple kinds of dynamic and time varying patterns are generated, which are known as teams' behaviors. This research is based on the assumption that we can find some common and fundamental mechanisms behind all teams from previous researches of cognitive science, cognitive anthropology, and other related fields. This paper attempts to model the mechanisms of computational structure, cognitive load adjustment, detection of errors and rework, experienced learning and task governance for a better understanding of teams.

## 2. Dynamic Behavior and Organizing Process

### 2.1.Dynamic Behaviors of Navigation Team

This research is concerned with a navigation team, which reorganizes itself to overcome environmental changes (Hutchins, 1996). Major focus is on time varying patterns of the team's performance and related cognitive properties, including cognitive load, mutual understanding among members, knowledge redundancy about tasks, task governance and sharing, and communication overhead among members. To understand these patterns is the model's purpose.

### 2.2. The Goals of Organizing Process

In the analysis of the navigation team’s response to environmental change, there exist interrelated and goal-seeking processes. The goals, implicit or explicit, of each process function as motivations of the team’s actions (Forrester, 1961). In the navigation team, processes seek major goals of performance, task quality, functional effectiveness, and cognitive load limitations. Among these goals, functional effectiveness is the most important, because without functional effectiveness the team can not move on and is in danger immediately. The figure1.1 to figure 1.3 depict the main structure of the navigation team under the purpose of team’s adaptive mechanism. Figure 1.1 illustrates a loop to maintain the alignment between desired performance and the team’s real performance. The loop also connects to an explicit cognitive adjustment loop, which represents team members’ efforts to change their ways of carrying out tasks for the reason of cognitive economy. Those changes may be new instruments, new procedures, or whatever depending on their environmental availability. Because those changes are unplanned behaviors, they also affect local interactions between members. Therefore, time is needed for the team members to rebuild their mutual understanding about interactions. Besides, members may ignore some minor tasks and lower task quality standards under extreme cognitive loads.

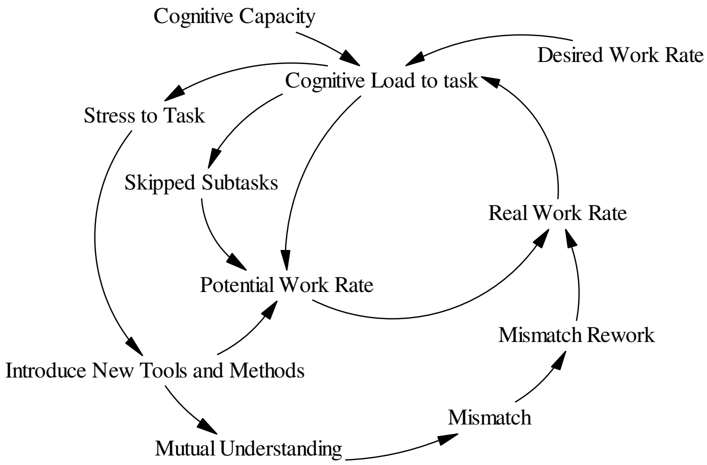


Fig. 1.1 Causal Loop Diagram of the Navigation Team's Adaptive Process 1

Figure 1.2 presents the members' self-regulating mechanism. Task governance is the way of collaboration among team members. It can provide more efficient learning environment for a new comer or higher quality of tasks performed by team members. For good honors or relationships, self-regulations are also essential. Both task governance and self-regulations take place when the team members have enough cognitive resources and knowledge redundancy. Knowledge redundancy is the team's overlapping distributions of knowledge among the members. To increase knowledge redundancy means that the team members have to spend more time to work together. However, when knowledge redundancy is too low, the team has no ability to perform task governance.

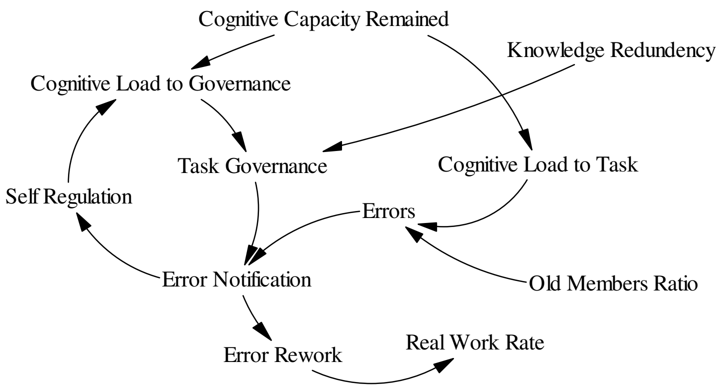


Fig. 1.2 Causal Loop Diagram of the Navigation Team's Adaptive Process 2

Figure 1-3 presents the mechanism of allocating human resources to achieve desired performance. The adjustment of the member size influence the old/new members ratio and the shared tasks' performances. In the navigation team, the member size is fixed. But when the desired performance is too low, members may transfer from other tasks temporarily. The figure also shows how the team's knowledge redundancy changes. By tasks performance sharing, members have opportunities to learn to learn the others' tasks, especially, under the motivation of maintaining the team's functional effectiveness.

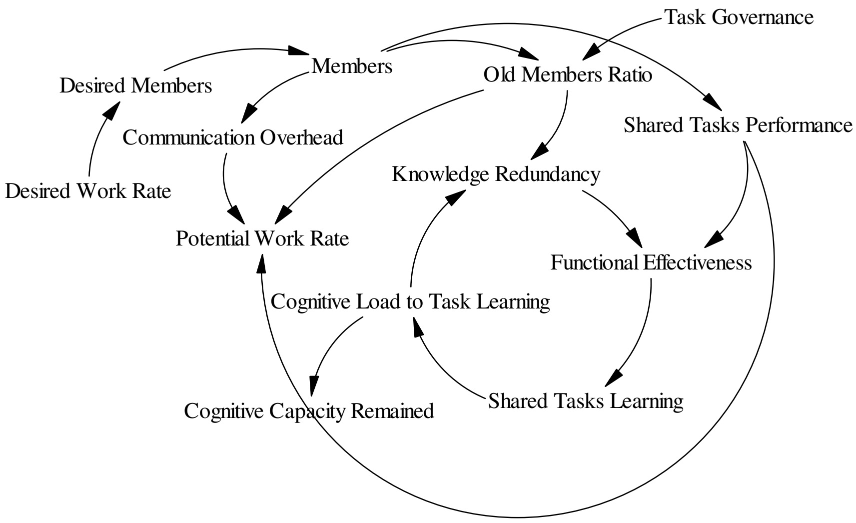


Fig. 1.3 Causal Loop Diagram of the Navigation Team's Adaptive Process 3

**3.Model Behavior**

This section discusses some variables' patterns of the navigation team in a real crisis. When the navigation team was navigating the board into a hub, the electronic power of the board was fail. Almost instruments in the navigation team can not run properly and the ship was very dangerous in that time. The time between the power failed to the ship anchored and stopped was about 120 minutes. In the model, this scenario is designed with desired work rate changes from 10.8 to 14.4 tasks/minutes at time 50 and potential work rate decreases to 60% against normal situation. The generated patterns are listed in figures 2-7.

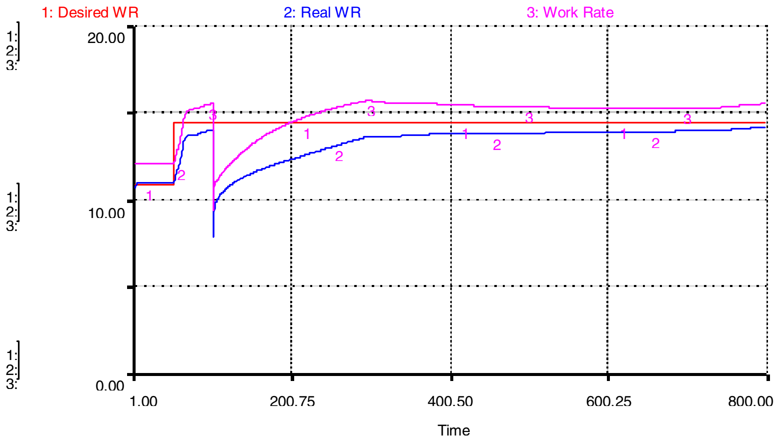


Fig. 2 Desired WR: desired work rate (tasks/time, at time 50,from 10.8 to 14.4), Real WR: real work rate (task/time), Work Rate: potential work rate (task/time, at time 100,decrease to 60%)

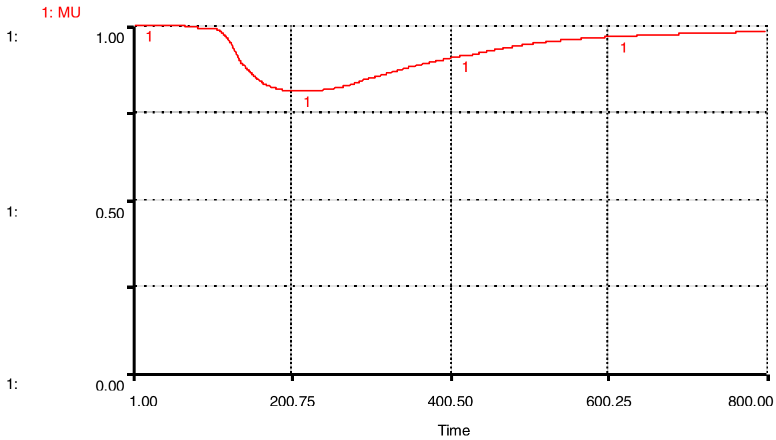


Fig. 3 MU: mutual understanding of operations between members (MU unit)

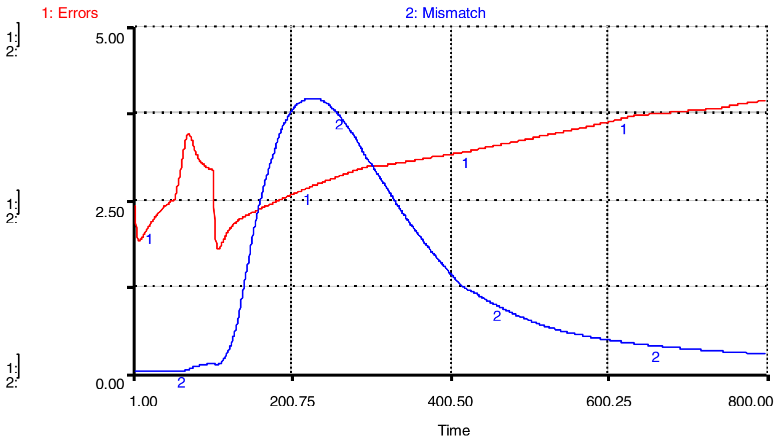


Fig.4 Errors: errors remained (error unit), Mismatch: mismatched remained (mismatch unit)

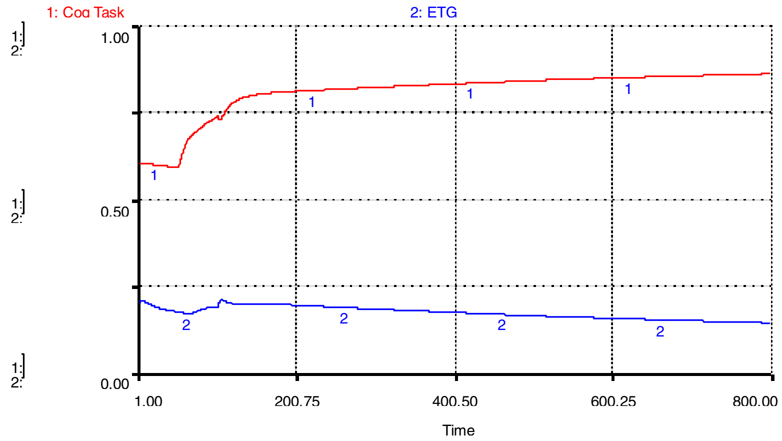


Fig. 5 Cog Task: cognitive load to perform tasks (cognitive unit), ETG: cognitive load to perform governance (cognitive unit)

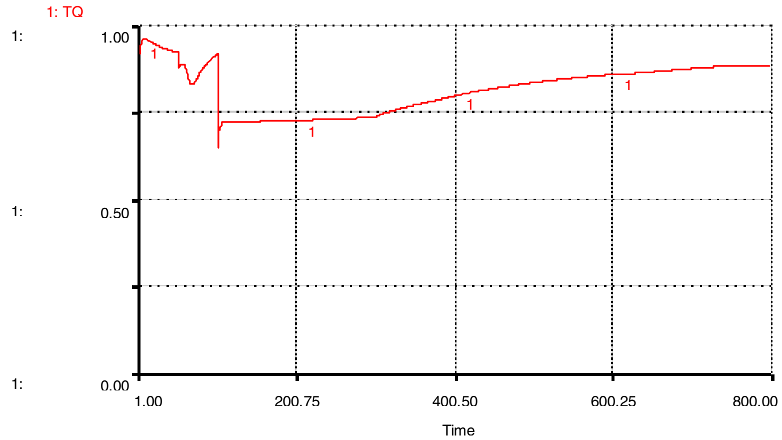


Fig. 6 TQ: quality of task performed (index)

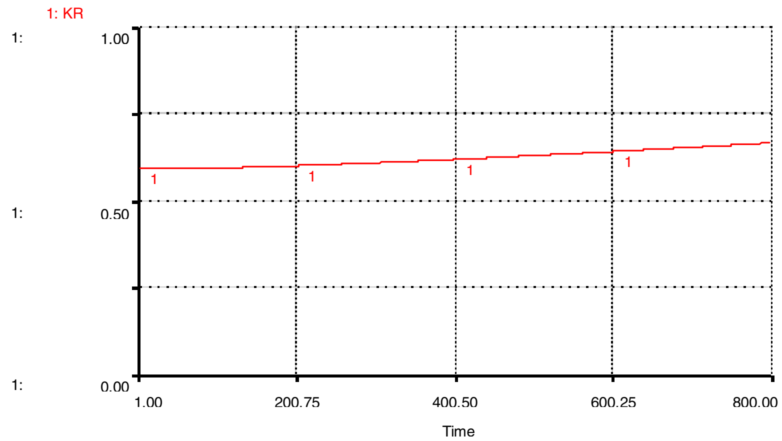


Fig. 3 KR: overlapping distributions of knowledge among the members of the team (knowledge redundancy unit)

## 4.Structure Design for Team Learning

By means of model developing and simulation, we can explicitly understand how a team could concentrate on and adapt itself to the environmental changes successfully. Adaptability is the most important capability of a self-directed team, and it is also the main merit for self-directed team to exist. Such a capability does not occur by accident, but is obtained from long-term structure. The sudden environmental change is a temporary event to the navigation team, but it reveals the team's capabilities to cope with certain environmental variations. The capability is determined by the way a team responds.

The competence of a system's reaction to the environment is determined by a routine structure, together with shared and distributed mental models (Senge, 1990). By the model we understand more about why a team can adapt successfully by self-organizing. The structure also indicates how a system gets the abilities needed to cope with uncertainties of environment. To understand the structure is to be aware of how the team learns. With the understanding and awareness, one can design and improve the structure by model experiments.

This paper illuminates that mutual understanding and knowledge redundancy are more important in this case. They are basis of a successful self-organizing of team. The behaviors of mutual understanding and knowledge redundancy are worthy of further endeavors.

## 5. Conclusion

This paper examines a team's self-organizing process in a dynamic environment with a quantitative model. With the mathematics model we can understand the interactions between elements more deeply than other method. Some operating mechanisms such as cognitive load adjustment and task governance are found to be more fundamental and common for self-directed teams. This research is just a beginning by approach to understand why teams can cope with the changing environment and how they to get and where they to get the abilities they need.

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