Methods to meet changes in the security environment a proposal of qualitative and quantitative assessment attributes for coordination performance

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ABSTRACT

The use of methods to inform changes of command and control has long been important, in particular through empirical surveys and computational simulation. In this article, we focus on a particular type of control: "bump-less" time-shift of authority during emergency response where it is not desirable to interrupt task resolution (Dess et al.,1984). As an example we address a particular type of control in a sociotechnical use case, i.e. ensuring coordinated action among human and non-human entities, and specifically use as a case shift of who ensures coordinated action when what entities are participating fluctuate over time, yet there is a need to sustain coordination (e.g. due to criticality of sustained performance). We do some work to detail a sociotechnical control mechanism and we present methods for examining the influence such control may have on performing both planned, prescribed, organizational task work as well as dynamic, non-prescribed tasks (Stanton et al., 2018). We argue that measures of high fidelity, with high specificity, defined before task resolution (feedforward) may be particularly important in prescribed change due to the possibility to define clear goals for coordinating and detailing who holds coordination authority. For dynamic change, on the other hand supporting technology that enable a sensing and processing of feedback the number of agents/entities undergoing change is not predetermined and the change of who is best suited to coordinate authority is less clear. Our theorizing is illustrated by using traditional linear control theory emulating shift of control nuanced by an emergency use case. In conclusion, we suggest future directions for research as well as practical implications.

Keywords

Modelling and simulation, multiteam systems, control theory, emergency response.

INTRODUCTION

Emergencies may be handled by organizations that are highly formalized and with a set number of entities or with emergent number of entities. To the latter: affected by disasters and crisis can itself be an important contributor shaping emergency systems. The affected community, with inherent internal resources imply resilience and capacity to respond in a crisis (Grant et al, 2014)[p.26]. This could mean that coordination is needed among external organizations and contributing teams, and local contributors with differing interests, and understanding of core activities. In order to develop such a perspective, we propose a changed "organisational paradigm"(Kuhn,1974;1994; Westbury, 2021) as a good starting point for theory which involves an increased focus on organizational "agility" and "resilience".(Johansson et al., 2015) Agility is the ability to handle and utilize new and unforeseen circumstances. Resilience is the ability to handle disturbances through robustness and recovery.

While the formal organizations can reduce uncertainty and be robust they may also need to develop to be agile and resilient in novel situations (Grabowski et al.,2019). This is particularly relevant when it is not desirable to interrupt task resolution (e.g. due to the strategic criticality of the task resolution such as in the ongoing defence of Ukraine). Facing the corresponding socio-technical (Walker et al.,2017) and organizational challenges, research on combining network science with command and control theory remains essential (Grant et al., 2014)[p.xxvi]. We propose to augment this largely structural paradigm with dissemination of system wide state(s) related small-world networks (Fenema, Kumar & Pentland et al., 2004).

Processes of structural change are shaped by the environment, and efforts are made, to control their “internal” emergence as well as their interaction with an environment. This shaping and control can take many forms ranging from hierarchical command structure to highly decentralized decision-making (Rico et al., 2018). In Cognitive System Engineering (CSE) like Extended Control Model (ECOM) and layers of control (Hollnagel & Woods, 1982) we find the emphasize on self-organization and local decentralized behavior in producing aggregate system outcomes similar to Complex Adaptive Systems (CAS) theory across levels (e.g. Kozlowski et al., 2000; Singfil, 2019), in contrast to traditional theories of central design and control. This can be seen as an organizational design (Daft & Weick, 1984;Daft et al.,1986;Weick & Quinn, 1999;Kauffman,1995) that take into account the multilevel nature of control and linkages across levels and entities.(Kozlowski et al., 2000). Moreover, the interaction of elements in a system can produce surprising, emergent behavior that can be modeled (‘fitness’) and applied to studies of organizational adaption.

However, we argue that a micro organizational design effort needs a framework e.g. ”control paradigm” (Fenema et al., 2004) and the environment in the planning and modification of actions (Hollnagel & Woods, 1982). While the “bottom up” approach to control is an important perspective a dilemma exists between no control (open system), versus tight control (closed system), and how to achieve a balance of observable and controllable states i.e. robust stability (Doyle et al.,1982). Furthermore, within organizations, these dilemmas may increase when the number of levels and entities increase (Sinha and Van de Ven, 2005). Crucially: How do one make both a centralized and decentralized type of control useful as tools by which practitioners can be supported in their decision-making for emergent organizations (e.g. participation fluctuates)? We narrow down our discussion to the case of coordinating among entities in both planned and dynamic tasks with a set number of entities to coordinate between or with a fluctuating number of entities. In a sense, what practitioners may want to do is to ensure the integrated action to accomplish a shared goal by established team of teams, multiteam (Zaccaro et al., 2012;Bienefeld et al., 2014) i.e. network of interdependent teams or a new multiteam is formed based on entities working together for the first time.

First, we present a traditional servo-control-closed-loop use case. Secondly, we develop a model for coordinated action in a "multi-team" setting designed so that we have the framework to "try" different coordination models early on i.e. evaluating principles for coordination. Third, we propose qualitative and quantitative assessment attributes (system variables) for coordination performance (e.g., metrics of coordination behavior in action, mediating understanding, and of interests) that enable component teams to attain proximal team goals and superordinate system goals (Mathieu et al., 2018). Finally, we propose various (design) approaches (Johnson et al., 2018) to develop coordination mechanisms (Miller et al., 2007)(e.g. enactment of control, handover and takeover techniques, objective functions) followed by a discussion at the end of the article on future research on various approaches.

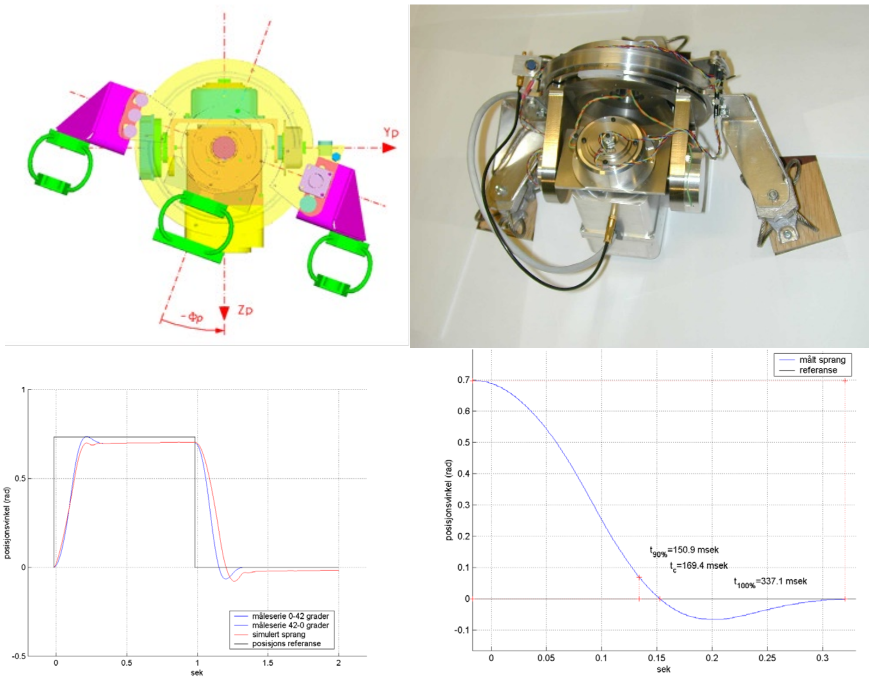
USE CASE

A demonstrator illustrates the use of linear servo control to stabilize a video-camera in three axes so that the desired image section is isolated from movement. The stabilization mechanism will also be able to be used for controlled positioning of the optical axis. The camera platform will in principle be able to keep the camera pointed at a target using information about the target's position in relation to a gyro platform. This is solved using several servo systems with the following functions:

1. Azimuth servo to control the movement of the camera if you want to scan the scene in front of it and to isolate the position of the image field from movement in azimuth.

2. Elevation servo to position the image field in front of it and isolate the positioning of the image section from movements in pitch.

3. Roll servo to stabilize the camera platform in roll.



Stabilized camera-pod (upper illustration) to keep the camera pointed at a target using information about the target's position in relation to a gyro platform (not shown). Servo control electronics (not shown) control the movement of the camera. Measured (blue lines) and modeled (red line) servo control response in pitch shown (illustrated in the lower section).

Figure 1. CAD-model and physical demonstrator of a stabilized camera pod. (Stensrud et al., 2001).

Reference signals necessary to stabilize the camera platform in relation to angular movements are supplemented from a navigation system. A navigation system calculates the orientation angles, which are mainly based on measurements from an inertial sensor unit. The servo system's physical units are shown in the Figure 1 (servo control electronics are not shown), and all three axes are controlled by DC servomotors. Angle encoders for the axes are resolvers. The demonstrator was made for educational purposes and the students working on it used simple linear control modelling tools (Mathlab) and methods (Margins in Bode-plot, Ziegler-Nichols methods and Nyquist-stability criterion) to configure the controller software (Stensrud et al., 2001) to optimize the servo controllers in use in Figure 1, we combine insights from cybernetic theory (Novikov, 2016). Later on in the text, we draw on an extant research on socio-technical systems theory mixing methods (Mingers, et al.,1997)(Moon et al.,2014). However, when referring to methods, we refer to simple rules of thumb like those mentioned above, as means to investigate reciprocal dependencies (interlinkages of workflow between teams) Thompson (1967) due to solving tasks and sub-tasks with inherent task complexity (Hærem et al.,2015; Schneider et al.,2017) and lead-time and time delays (Brehmer,1992).

METHOD

As a framework for our analysis, we introduce in this article, a method used to implement, analyze and evaluate some specific design principles (McNeese et al.,2018) that can be used by the actors in an organization to control the process of constant change(e.g. a “change case”(Fiammante, 2010)). We use the theory (and metaphor) of servo control Flach (2004). Servo control theory is an interdisciplinary branch of engineering and mathematics that deals with the behavior of parameterized dynamical system. A physical implementation of a servo control loop consists of a motor, a resolver or encoder measuring the position of the motor shaft providing positional feedback of the motor shaft to achieve high-performance motion tasks (e.g. a stabilized camera pod as shown in Figure 1). When one or more system variables need to follow certain references over time, a control engineer manipulates the parameters of the servo controller to obtain the desired effect (movement) in Figure 2. (Janssen et al.,2014 p.174).

A metaphor can be defined as “a way of thinking and a way of seeing” (Morgan, 1997, p.4) cited in Kamoche et al. 2003, p. 2031. The Hand and Brain metaphor of Motion Control of Figure 3 illustrates an organizational context in order to help us see organizations in a new light, thus generating useful insights into the phenomena of "organizational collaboration". Motors are like our hands; they can perform tasks, but they need a brain to tell them what and how to do it. In motion control, if servo motors are the hands of the "servo body", then the servo drive is the brain, and to extend the anatomy metaphor further, the nervous system of the servo body. Once the servo brain has decided where and how to move, it fires electrical signals to command the desired motion of the motor. (Janssen et al.,2014 p.174; Christison, 2021). We analyze the effect of these principles on utilizing coordination mechanisms, i.e. the use of behavioral strategies and guidelines to integrate and align the actions, knowledge and goals of component teams to achieve common goals (Okhuysen, & Bechky,2009;DeChurch and Marks, 2006, Cited in Rico et al., 2018), and in turn their effect on performance. We provide a rough and simplified example of a specific coordination mechanism, i.e. the integrator role sometimes named the coordination form (Mathieu et al., 2018) i.e. who enact coordination functions, and the need for updated observations, predictions and decisions (OPD) and design requirements. (Stensrud et al., 2020a). In the model of both the prescribed dynamic behavior of actors, one must take into account the interdependence between the different teams (Janssen et al., 2014, p.152)(pupil-teacher socio-metrical longitudinal relations studies: Hox et al., 2005)(problem-solving and play:Bruner et al., 1974).

MODEL

Previous work found, there are presented frameworks and models for coordinated action in a "multi-team" setting (Rico et al.,2017). In addition, with the dynamic decision loop(s) and time sensitivity dilemma in mind, there are few contributions fully developed with applied business process models for changing forms of interaction (Rico et al.,2018). In addition, with a selection of criteria for changing them (Stensrud et al., 2021) "the structure (e.g., boundary-spanners, members, centralized, decentralized) of who in the MTS enacts the coordination functions," (Mathieu et al., 2018). In an emergency response system, coordination is central to the outcome of whether the effort achieves the desired result (Lanaj, et al. 2013). Given that the effort has access to a limited selection of free / tied resources, great demands are placed on the harmonization of activity and interests (Valaker et al, 2020).

When involving teams/agents (e.g. contractors), a so-called "intentional loose coupling" (Weick, 1976) of interests requiring a task assignment or a set of sub-assignments should primarily include a coordinated and agreed, overarching objective. Secondarily, with a description of purpose, and formulated as an associated resource allocation schema, as well as rules of actions, which, as far as possible, leave it up to the contractor to determine the procedure and decide on the alternative course of action. We introduce a mechanism balancing structure and process, i.e. multi-level theory already well established. In this article we cross-pollinate multi-level theory (Braun et al.,2021) with what Braun et al (2021) conclude multi-level researchers need is "new" theory. A model building on Grant & Janssen (2014) contributions on command, control and network theory, with our emphasis on a selection of relevant attributes for initiating and implementing "bump-less" time-shifts of authority during emergency response handling a dynamic multi-level process (Westbury, 2021;Brehmer, 2011).

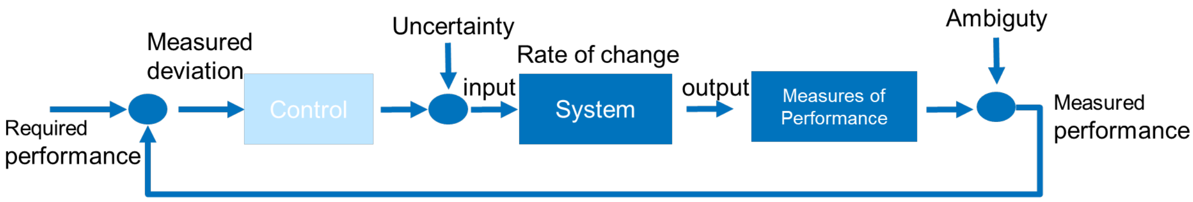


Figure 2. Model for coordinating responses in a "multi-team" setting. (Janssen et al., 2014, p.154).

We assume that conditions are set for the emergency response system to be controllable and observable. A stable system requires a control mechanism that produces a steady flow of information about the system's state and "senses" the environment (i.e. world state). An observable and controllable system is ideally not possible to design or model. However, minimizing temporal friction that may occurs for a number of reason, in order to maintain task resolution at a desired level, when coordinating responses in a multiteam system, is of interest. Consequences of not having updated the system state can, in the worst case, lead to incorrect assessments (Karl Weick's «Collapse of sense-making in organizations») that can cost lives and health (Coze,2015). Regardless of whether this is due to a lack of understanding, conflicts of interests or regular communication interruptions, friction or disturbances will affect the agency/management of its own resources and prioritization of those who need it most in emergencies. Besides that the decision chain is expected to support situational updates on the outcome of the ongoing efforts / results, the influence of temporal aspects of dynamic tasks methods chosen on idealized continues control system performance, is well known. E.g. *time constants* in the decision between the moment when the action has started and that when it takes effect, what control engineers usually call the time constant of the process (i.e. *lead time*). Replacing a continuous system into discrete time form is always an approximation of the continuous system. A sample/hold-mechanism introduce *dead time* when coordinating teams in emergency response systems (Brehmer and Thunholm, 2011, p.7) inherently additional temporal aspects of *information delay* and *decision time* are sources to *friction* in the dynamic decision loop that is inherent in crises responses.

In order to control a system, the controller has to show at least the same variety as the target system's variety. By applying analysis-tools a "mapping" of the coordination and the interdependencies may be undertaken. This is thus ways of making the entities relationship with it each other "observable". Ashby's Law was framed in the context of his interest in self-regulating biological systems, but it was rapidly seen as having a relevance for other kinds of systems (Seidl et al., 2018). The British cybernetician and operational research practitioner Stafford Beer, for example, used it as the basis for his concept of a *viable system* in organizational design. In colloquial terms, Ashby's Law has come to be understood as a simple proposition: if a system is to be able to deal successfully with the diversity of challenges that its environment produces, then it needs to have a repertoire of responses, which is (at least) as nuanced as the problems thrown up by the environment. (Ashby,1956;Beer,1959;1994; Bateson, 1979;1988;2000; Harries-Jones,1995) Cybernetics leads to management (Easterbrook, 1960) and socio-technical systems (Fitts lists'; Fitts, 1956) and renewed attention to human factors during the 1980's and 90s (Endsley, 1995; Weick, 1976) with the consequence that actions are seen together, users are seen as parts of a whole and influence of the situation is direct, and models are functional rather than structural.

That said we introduce structural metrics as a practical example of metrics in this paper in line with the recommendation of Stanton et al. (2013). The methods we introduce should be seen as building blocks in a larger control mechanism, in that they do not by themselves indicate the specific alternatives for who is going to hold the coordination responsibility in the future. The findings of structure in particular cases we argue should be compared to desired shared goals of the multiteam in order to form "predictions" and "decision" about who is likely to best hold the coordination responsibility. Thus, one should not necessarily change the particular structure one sees based on historical data or predefined rules, but rather analyze whether it is useful for the task at hand to change the structure.

Simple mathematically modelling methods when implementing different approximation methods give different digital controller performance. Designing an organization optimized for coordinating responses in a multi-level, multi-variable setting will depend on how input management and output management are treated i.e. handover and takeover of information. The sample-hold mechanism can be compared to the transaction of authority (to whom sending information) and handover-takeover mechanism when exchanging situational awareness in a mutiteam structure. Handover-takeover techniques (HTT) are routinely carried out at certain times (Clark, et al., 2019). The design of system input (i.e. capacity of handling information) will cause a rate of change of the system wide state(s) depending on how often one receives feedback illustrated in Figure 2. Feedback as described in Dynamic Decision Making (DDM) (Brehmer et al., 1992); prediction of outcomes and planning; practice and training (Johansson et al., 2003) may thus affect the system and the decision-making chain as shown in Figure 3.

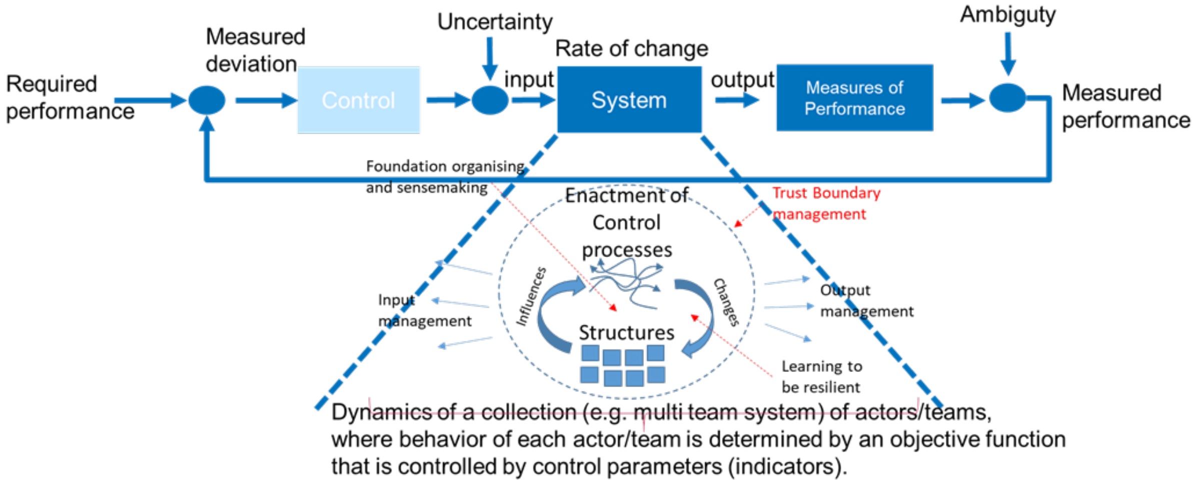


Figure 3. Model for coordinating responses in a "multi-team" setting (Janssen et al.,2014,p.154) with an emphasis on a selection of attributes (Westbury, 2021).

Qualitative assessment attributes (Modes of Operation)

Designing an organization template for coordinating responses in a "multi-team" setting (Figure 3), we will need to develop a flexible organizational model, which makes it possible to change the form of the efforts dynamically adapted to changes in the environment (Sinha & Van de Ven, 2005) balancing the hierarchical level problem, network complexity and modularity problem (Dooley et al., 2021). This may require that data is collected not only on entities that have certain well-known attributes (e.g. fighter aircrafts and battle tanks in own inventory) but also is acquiring data according to an "open" sourcing of data on less defined entities (e.g. voluntary entities). Most important, not necessarily introducing advanced new technology, we will need to create and establish a robust and stable response that is based on the actual performance of a (sometimes) evolving and expanding organization. Given a First Entry response scenario: How do we design a proper "sample/hold" mechanism that "propose a general harmonization between the Controller of the closed loop and the Evolutionary Control processes"?

The dynamics of a collection of actors/teams, where behavior is to be controlled need norms (mathematically definition) outlining metrics e.g. "calculating" closeness and complexity of working relationships (Allen et al.,2011), i.e. collaboration (Alberts, 2009; Alberts et al., forthcoming). Further, how do we design the split between those parts of an endeavor facilitating the collective, and the part organizing those participating directly in an emergency response effort (coordinating the level of work)? To identify key enablers to improve performance – i.e. identify work patterns – a traditional and most common approach is to build robust multiteams through ongoing training (skill development measures) to solve the modularity problem– i.e. broad investment in skills (people), development of rules, and intensive and expensive team-training programs. In theory, certain driving rules (Situation Awareness Design Guidelines) should be followed (SOPs, TTPs) (Clark et al., 2019). However, training is no substitute for effective system design, thus actors who know patterns and routines, drills, procedures - and are made familiar with pre-defined programs for carrying out partial tasks, may qualify to coordinate e.g. take part as boundary spanners solving the network complexity problem.

Table 1. Modes of operation (Langeland, 2022; Rasmussen, 1982; Snowden, 2015; Stanton, 2013)

Modes-of operation (attributes)	Type of control	Input management	Output management	Reason-for-action	Performance driven by
Manual mode	Open loop	Actuation	Command	Do the things	Skills
Primary automation mode	Feedback control (world state reported to controller)	Target	Control	Do things right	Rules
Alternate automation mode	Feedforward control (estimated world state)	Prediction	Plan-based	Do planned things right	Information (intel)
Contingency automation mode	Feedback,& feedforward control	Reflexive,& predictive	Command,& control	Do right things	Knowledge
Emergency fully automated mode	Feedback,& feedforward, with a goal generator	Reflexive, predictive,& adaptive	Adaptive command,& control	Greater good	Intrinsic values

Enactment of Dynamic shifts of Coordination in a bumpless way

A control engineer will say that the main challenge lies in modes of operation and instrumenting and synthesizing feedback. The inserted Table 1 is included to clarify the meaning of bump-less transfer between *Modes of operation*. Bump-less transfer is the method by which a (servo-) controller can be transitioned from Manual mode to Automatic mode without disrupting the process. Sources of the bumps in a servo-control loop are caused by the fact that the output of the controller are under direct control, and the controller still operate as is in automatic control of the devices under control. In worst case, integral action of the servo-controller will “wind-up” to either max or min output of the servo-controller output. If this is allowed to occur then there will be a major disturbance when the transfer from Manual back to Automatic mode is made.

We are primarily concerned with looking at the first two rows of Table 1, i.e. handling shifts of coordination (activities, interests and understanding). Primarily when tasked in a crisis, a military unit will be scrambled off by an actuated command to targeted control, supported by mechanisms for “bump-less” time-shifts of authority when changing the Modes of operation, e.g. from a Manual mode to Primary automation mode. If Modes of operation are shifted further down the rows in Table 1, how do we facilitate this without disrupting the main processes in Figure 3?

While we may both vison shifts in who ensures coordination, supported by varying types of technology, it is not straightforward to examine the utility of such shifts on solving various tasks. Different types of change may be important due to the differences between tasks: We propose that in prescribed tasks a prescribed change of who ensure coordination could be appropriate (e.g. from one centralized command to another centralized command but at a lower level) typically. Normally, this is what happens going from a transition phase to an action phase. Whereas in dynamic tasking the shift may go from one node to a number of different other nodes depending on the actual entities involved in joint activities (the “best” entity to handle coordination responsibility would be less possible to specify beforehand here than in the prescribed task). A transition of authority should be implemented with care by using suitable Handover-Takeover Techniques (HTT) as a mean to minimize time-delays (wait-and-stop) during task resolution.

Enactment of Controlling Systems’ state

To update the system wide status at the rate pace and disseminate a steady flow of information elements about the system's (internal) world state to the users, the “interface” will ideally inform about the effect of “sampling/hold” by feedback to users through continuous updates and learning. In addition, an emergency response system – need output management and a trusted boundary management (i.e. safety and security of the human-in-the-loop). Visualization (e.g. a dashboard keeping track of the system wide state) can potentially make a difference regarding controllability and observability i.e. making emergency response systems less vulnerable to changes e.g. input management and transport delays (ketchup effects). The task allocation may be tailored to the qualifications and skills of the users - both in terms of the content and the form of interaction (e.g., reaction times or workload) by an informed system wide information management. (Cvetkovic et al.,2022) In addition, an identification of possible procedures for Open-Loop Control (pre-programming, fuzzy-control) is an alternative for the closed-loop model in Figure 3. (Kim et al., 2016) (i.e. row one in Table 1).

Foundation Organizing and Sensemaking

Organizational structure (in Figure 3) we define as “the sum total of the ways in which labor is divided into distinct tasks in order to achieve coordination”(Mintzberg,1979;Dodd et al.,2004) and as opportunities for communication between group members, characterized by different degree of centralization of decision authority (Katz et al.,1978). In this respect organizational structure (which in our case is synonymous with coordination form) can tell about who is most important in coordinating at any given time as this could be considered a distinct task of its own. It should be noted that coordination may be “programmed” and enacted by teams holding a shared mental model, therefore the ongoing coordination responsibility may be two things; to initiate activity and to handle exceptions due to a predefined initiation order. It is this specific aspect of coordination through one or more entities, we focus on.

Organizational structures, such as the structure of who coordinate during task resolution, furthermore influences and change due to patterns of interrelated rules, practices and resources. This follows Giddens’ Structuration theory.(Gezgin,2016). An organizational developer consultant will say we need to measure who do what, when in the organization during an emergency response. We augment structuration theory with concepts of affordances, in that the skills, rules, and practices provide resources for individuals and groups that enables them to do right things e.g. transforming knowledge across boundaries building competence (Carlile, 2004). Additionally, to measure change in coordination form (semi-dynamically) we apply two alternative graph measures to characterize the structure and dynamics of a coordinating collection of actors/teams, where coordination form of each phase is described by a graph. Figure 4 presents a response to an emergency (military exercise) exiting a sample-hold mechanism that illustrates an aggregation of all the phases of an activated multiteam system in an emergency response scenario i.e. a graph representing (1) initial relationships between the teams and (2) an emergent graph representing the new relationships between the teams participating (Figure 4). (Valaker et al., 2022)

Quantitative assessment attributes (the coefficients of assortativity (Newman,2003) and centralization (Freeman,1978))

We introduce two alternative graph measures to characterize the structure of an organization described by a graph are the coefficients of assortativity (Newman,2003) and centralization (Freeman,1978).

Table 2. The assortativity coefficient (Newman,2003)

	The nodes are all communicating between levels of an organizational structure.	**The nodes are equally likely to communicate between as within levels.**	**The nodes are all communicating within levels of an organizational structure.**
r-value	$r = -1,$	$r = 0,$	$r = 1$

The assortativity coefficient describes to what extent a node is related to other nodes of the same type. Here type can refer to any attribute of the nodes, both discrete and continuous. In our case, we choose to let the type be indicated by the level at which a node in the organization is placed. The assortativity coefficient will then characterize whether the organization predominantly relies on lateral communication (within levels) or vertical communication (between levels). It seems reasonable to associate the former with a lateral integration mechanism for the MTS and the latter with a hierarchical integration mechanism (Lawrence et al., 1967), as described in (Rico et al.,2018). For a discrete, enumerative type i, let e_{ij} denote the fraction of edges in a graph that connects nodes of type i and j, and a_i and b_i be the fractions of each type of end of an edge that is attached to a node of type i. Newman's assortativity coefficient then takes the form (Newman,2003)

$$r = \frac{\sum_i e_{ii} - \sum_i a_i b_i}{1 - \sum_i a_i b_i}$$

In the case where i indicates the organizational level of a node and the edges represent communication between nodes, an r-value of one will describe an organization where all communication takes place within levels, and $r = -1$ characterize an organization with purely between-level communication. With, $r = 0$, the nodes are equally likely to communicate within as between levels (Table 2).

Table 3. The centralization coefficient (Freeman,1978)

	Indicating all nodes being equally central in an organizational structure.	**Indicating extreme centralization in an organizational structure.**
$c(.)$	$c = 0,$	$c = 1$

The centralization coefficient describes the degree to which the centrality of the most central node exceeds the centrality of all other nodes (Table 3). It is defined as (Freeman,1978)

$$C = \frac{\sum_i^N |c(n^*) - c(n_i)|}{\max \sum_i^N |c(n^*) - c(n_i)|}$$

Where $c(.)$ denotes any centrality measure for a node, n^* is the node with highest centrality in the graph, and the denominator normalizes the measure by taking the maximum possible value of the numerator over all graphs with N nodes. C then takes values between 0 and 1, 0 indicating all nodes being equally central, and 1 indicating extreme centralization. This measure can be used to analyze the effect of these principles on the metrics for coordination and synchronization of a social network (graph structure) as a whole.

Toward a rapid evaluation support metric applied to networks of teams in an emergency response

To demonstrate the approach, we will in future research apply it to emergency response system's social networks in which the metric: centrality and to what extent a node is related to other nodes of the same type, is evaluated *on-line (rapid evaluation support)*. Figure 5 illustrates how the assortativity and centralization coefficients vary with operation phases in an emergency response scenario. A negative assortativity index implies a dominant role of between-level communication. We conclude that this pattern is most dominant in the transition phases, but is less pronounced in the action phases. We also observe that the degree of centralization steadily declines as the operation proceeds. Application of the metrics for an emergency response scenario is illustrated in Figure 5. (Valaker et al., 2022)

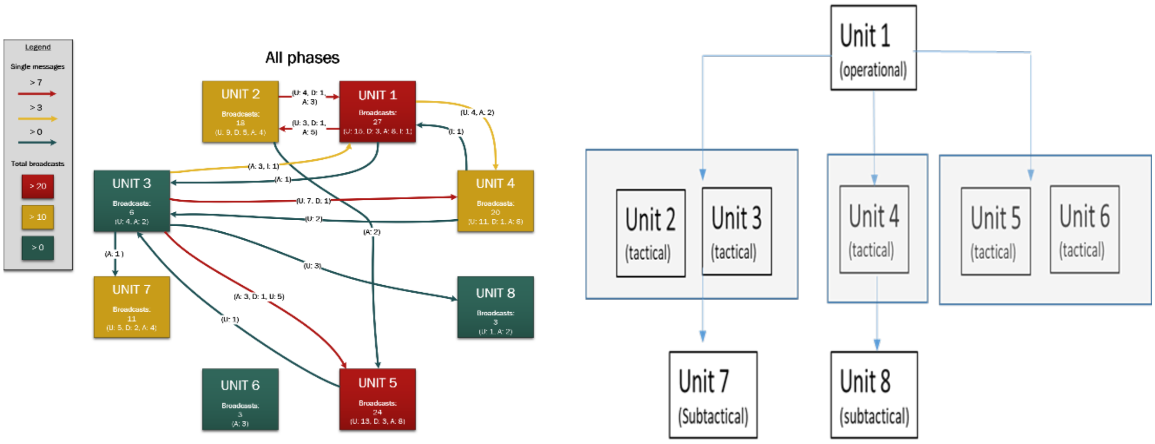


Figure 4. Example of unformal (left) and formal (right) organizational structure of a multiteam active in an emergency response scenario. (Valaker et al., 2022)

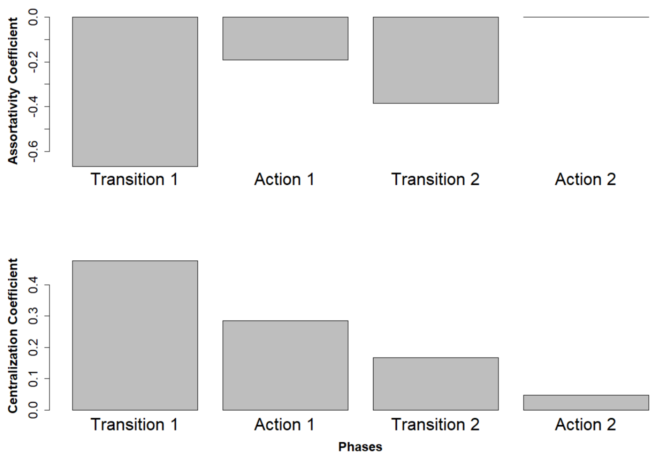


Figure 5. Assortativity and centralization versus operation phase measured during an emergency response scenario. (Valaker et al., 2022)

DISCUSSION

The automatic control system has been an important metaphor guiding research on cognitive systems. This metaphor has helped us to appreciate goal orientation within cognitive systems. It has also helped us to appreciate the closed-loop nature of perception and action. However, as with any metaphor, there are important limitations with respect to the phenomenon being represented - in this case, the dynamics of cognitive systems or the dynamics of sensemaking. One important limitation is that the source of goals and values is extrinsic to automatic control systems, but an intrinsic aspect of sensemaking. A second limitation is that the control and observation problems tend to be modularized in automatic control systems. In this context, the observation problem is reduced to the information-processing problem of filtering signal from noise. (Flach, 2004).

Organizing a coordinated effort requires an emergency response system, partly prescribed and partly organized as an emergent effort. How do we realize a dynamic relationship between organization and teams and individuals to enable the pooling of collective abilities and endeavors as a joint effort unfolds in practice? Routine and creative compilation of collective command and control functions (as exemplified in Granåsen (2011)) as practice unfolds - should to some extent be adapted to context and surroundings. A context-sensitive and adaptive mission strategy will depend on whether life and health are safeguarded and satisfy "the best we can do given what is out there".

Assumptions to realize a coordinated effort require understanding and aligned interests. We define coordination as the integration of knowledge and activities to achieve a common goal. (Rico et al., 2018) Coordination needs arise when there are dependencies between units. (Davison et al., 2012). Much research already on the relationship between interdependencies and coordination mechanisms. (Van de Ven, Delbecq & Koenig, 1976; Rico et al., 2018) To a greater or lesser extent, emergency response organizations can have knowledge proactively (feedforward) and reactively (feedback) as a basis for change and as a knowledge basis for coordination. Feedforward supported by models of the system such as plans and shared mental models (Wickens, 1992; Brehmer, 1992; Rico et al., 2018) may mitigate the weakness of goal-orientation of social systems. However, rigid social systems can be vulnerable to rule-oriented goal management i.e. unsolicited feedback is suppressed, tactical units' inability to read risk, decision-makers without ownership of consequences, failure to learn and manage complexity and strain on related systems.

To look at this socio-technically (Walker et al., 2008) and by using different system theories such as dynamic decision-making (Brehmer, 1992; Carleby & Johansson, 2018) or by organizational processes theory (Snowden, 2015) time and temporal conditions are a decisive factor for the opportunities to influence a development of events (Brehmer, 2013). The development of events can take place at different paces, which place different demands on rapid action and thus how quickly decisions must be taken and communicated. (Brehmer, 2006). Observation and Decisions (OD) (when leaving out prediction) supported by the theory of Dynamic decision-making (DDM) can be said to be activities that can potentially be routinized. Holding the state can in itself be seen as a routine as the information (feedback) on state is sent out to other entities regularly (repetitively), or entities check for the state of other entities (i.e. they observe) regularly. In other words, the “state holding routine” may unfold in different ways depending on whether it is decentralized or centralized. Such a model requires a distinction be made between different parts of a routine.

Perhaps by using Mathieu's conceptual apparatus: then interests and understanding perhaps become OD and then enactment (activities) become "the rest", i.e. an execution task set with metrics i.e. attributes. A question that arises then is how to distinguish between routines in order to distinguish attributes and instrumentation of these (Hox et al., 2005). A challenge here is that the three: interests, understanding and activities themselves, do not necessarily take over other relevant actions such as trust building, politics, system layouts, supportive technologies, etc. other conceivable actions in transition or tasking phases. However, in the article we claim that task allocation can be "solved" by saying that it is coordination that we focus on, and saying that in parallel there are other action (potential) routines and other actions are taken by the actors according to specifications (“best practice”, “best effort”) Henderson, I., & Coning, C. de. (2008).

A static (manual mode of operation) method would initially be to do a de-composition on a selection of variables: organizational level, resources and management, and risking stationary gaps in the emergency response system output due to missing feedback (Dodd et al., 2002). Making a distinction between adopted and formalized codified organization (distinction between capability and capacity). In Figure 3, the emergency response system's possible elimination of gaps are illustrated using a simple closed-inner-loop cyclic-model (enactment of control processes), i.e. one seeks to distinguish between possible ability and real ability to make efforts according to the arguments below (Westbury, 2021). Assumption and research question: That organizational capability is an indicator of organizational flexibility (agility) and resilience that can release the possibility of dynamically manifesting coordinated efforts; interaction, supported by theoretical models and criteria for effective management and governance. Previously, we have proposed mechanisms of enactment of control, handover and takeover techniques, as means of coordination. (Stensrud et al.,2020b).

Drawing on theoretical perspectives of organizational environment, we discuss some models of integration using a metaphor from the literature on servo-control, i.e. behavior of a parameterized dynamical system to underline the need for minimizing temporal friction. We may extrapolate this to organizational task work with what team of teams dynamically do i.e. team adaption(Burke et al.,2006). We claim that a Sample-hold mechanism can be compared to the handover-takeover mechanism when delegating formal authority (to whom exchanging information) in a team structure. However, a dynamic shift of authority may introduce *friction* in the dynamic decision loop (Brehmer & Thunholm, 2011) caused by ill-designed handover-takeover techniques (HTT) that are routinely carried out at certain times. (Clark et al.,2019). The organizational environment may vary along the following characteristics: uncertainty and ambiguity (Scott & Davis, 2016), where uncertainty can be divided into complexity (number of elements and number of relations among elements in an environment) or dynamics (the rate of change in elements in the environment; for a summary see (Stensrud et al.,2023; Grote, Kolbe & Waller, 2018; Luciano, Nahrgang & Shropshire, 2020). We discuss ways of handling such environmental contingencies. The following hypothesis are suggested: Defining and probing what situation is to be tackled could ensure using the available structures. E.g. not using a decentralized structure in high stakes situations. For example this criteria need however to be weighed against the practicality of using a centralized structure (Hollenbeck et al., 2018; Johansson et al., 2018). We draw on the suggestions by Van de Ven, Ganco & Hinings (2013) and Albert & Ganco (2021) to test general models within concrete circumstances and specifically discuss some key tenets of orchestration of teams and technology. Moreover, we proposed some qualitative and quantitative assessment attributes for coordination performance that enable component teams to attain proximal team goals and superordinate system goals (Mathieu et al., 2018). In the future, we ought to broadly examine the consequence of increasing numbers of entities and the consequence of different collaboration techniques used (Stensrud et al., 2023).

FUTURE RESEARCH

In future research, we are planning to extend our simulation and modelling environment to generate behavior of agents and entities. In our current work, we focus on a particular type of simulation: computer-supported human-in-the-loop (HITL) simulation (Valaker et al, forthcomming; Henriksen, 2022). We address what influence computer-supported HITL simulation may have on planned, prescribed, and more open-ended, constructive, organizational change (Valaker et al., forthcoming). The main purpose of the simulation is to contribute to the development of the decision-making and coordination done to counter novel threats. This involve improving the use of the capabilities of the Norwegian Air Force such as the F-35 stealth fighter jet. One of its primary uses has been to develop procedures for connecting the F-35 to other services capabilities in different types of missions. For example connecting it to frigates and to land artillery.

Moreover, to simulate the dynamics of a collection of autonomous actors, where behavior of each agent could be balanced by a cost-benefit objective function controlled by a prescribed and emergent set of control parameters (i.e. attributes), we will need to try out different sample and hold mechanisms in future computer-supported simulations. A potential change of goal setting: or shift of authority or task allocation among teams in a simulated environment of agents, will be depended upon updating and re-generation of information elements (Mercado et al.,2016)(Seeber, et al.,2019)(Stensrud, et al., forthcoming). An example is support of autonomous search and rescue operations (e.g. generating a concurrent map) and methods to propose beneficial scanning of search areas - how to physically scan areas with different a priori probabilities of detection and how to generate a priori maps. E.g. an modelling effort to dynamically adjusting allocation of tasks kept in a synthetic environment and the re-fill of resources will be investigated to keep track of the enactment of control processes and structures with the aim of identifying system attributes estimated by machine learning (Karali et al.,2023).

In the article, we have presented a model illustrating an effort of coordinating emergency response (in theory). In other words, our brief analysis indicates that there are trade-offs between the prescribed and emergent part of a future modelling effort to generate decision support guiding the muti-team endeavor. We propose an "organisational paradigm" as a good starting point for theoretical exploration. We illustrate our proposals through a simple closed-loop model, but need empirical evidence that gives further nuance to our theoretical discussion on bumpless time shifts of authority in a coordinating endeavor of emergency.

Admittedly, our research is preliminary, and more efforts should be made to develop models for emergent response systems initiating dynamical mechanisms controlling structural changes. We plan to carry out studies and experimentations in our own work that may provide richer data on the role of simulating control of organizational changes (Valaker et al., forthcoming). In addition, we see several areas for future research like coordination forms: Reviewing conceptualizations of Robust control (Doyle et al., 1982; Moody, 1989) Complex Adaptive Information Networks (Moffat, 2014) and Graph theory (Freeman,1978; Newman, 2003).

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