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Context Awareness and Context Recognition for an Increased Role in Pan-Domain Command and Control Decision Making Process—A Scoping Study

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Abstract

The pan-domain command and control decision making process takes place in an increasingly dynamic and complex environment. Today's domains include not only the traditional domains of land, air and sea, but also digital age domains such as space, cyber and information. The speed at which the environment changes has increased and commanders require new ways to adapt to changing contexts in which they exert authority and implement mission intent.

This technical report presents a scoping study in which the changing dynamics of context recognition and awareness are mapped and a command and control task model based on this mapping is outlined. It is divided into three main sections. The first section reports the results of a literature review on context awareness and context recognition, providing an overview of key terms and review the state of the art on the topic. Context recognition is described as a process of representing complex environments as characteristic schemas, frames or models, and identifies the roles these abstractions play in decision-making in terms of data, information and capability. The second section presents the results of a command and control task analysis based on both the literature review and interviews with Canadian Forces command personnel. A circular graph-based task model is proposed depicting the multiple simultaneous influences of task domains on each other, as an effect of context, and as a basis for context recognition. Finally, the third section suggests avenues of future research that may expand our understanding of context recognition and identify how the use of digital technologies such as artificial intelligence may assist commanders in context recognition and decision-making tasks.

Literature Review

Summary

This review identifies relevant materials in the federal science database, focusing on key terms within the domain of military and naval science, in addition to related work found through expanded-search techniques on the World Wide Web. The review is conducted within the context of the pre-defined concepts of ‘command and control’.

Following considerations related to definitions of ‘context’ and subthemes such as ‘context awareness’ and ‘context recognition’, which depicts ‘context’ as a type of generalisation that can lead to appropriate response, the review identified three major interpretations: context as schema, context as frame, and context as model.

A schema is a semantical framework that helps individuals organise, process, and store information about their environment. It can be thought of as a semantic concept composed of two major parts: significant words or symbols interspersed with blank-space placeholders; and a method or condition specifying how the placeholders are to be filled to obtain instances.

A frame is a psychological attitude defining a set of background assumptions and expectations. (Lakoff)

A model is a scientific or computational construction defining an environment, process or system. Models may be deterministic, stochastic, or probabilistic. Types of model include a logic model, mental model, simulation, or multi-objective optimization.

Working definitions

Pan-domain Command and Control

PDC2: Pan-domain Command and Control. For example, of joint forces (ie, army, navy, etc).

Pan-domain: as a term, is applied exclusively by Canadian Armed Forces (CAF). Pan-domain operations “include space, cyberspace, and the information domain, as well as the extant domains of land, sea and air” (Vance, 2020).

Command and Control *(verbs):* According to Canadian Military Doctrine, “Command” is the purposeful exercise of authority over structures, resources, people, and activities.

"Control" is inherent in command; to control is to regulate forces and functions to execute the commander's intent." (JS-1 505)

"The essence of command is the expression of human wills, an idea that is captured in the 'commander's intent' concept. Nearly everything commanders do is driven and governed by their vision, goal, or mission and the will to realise or attain that vision, goal, or mission." (Ibid.)

Command *(noun)*: The authority vested in an individual of the armed forces for the direction, coordination, and control of military forces. (DTB, Record 27866) (DTB: Canada's Defence Terminology Bank (DTB) (accessible only on the National Defence network))

Command and control (C2) *(noun)*: The authority, responsibilities and activities of military commanders in the direction and coordination of military forces and in the implementation of orders related to the execution of operations. (DTB, Record 13802) (CONT) "The functions of command and control are performed through an arrangement of personnel, equipment, communications, facilities and procedures which are employed by a commander in planning, directing, coordinating and controlling forces in the accomplishment of his mission." Ie., authority + direction

Defining Context

Context: "Any information that can be used to characterise the situation of entities" The term 'context' is frequently used in conjunction with terms related to capability or capacity, such as 'context recognition' or 'context awareness'.

Context Awareness: "Current characterization (as described by pattern, scenario, type or template) of the situation of entities", ie., "the ability to detect, sense, interpret, act and respond to relevant aspects of the environment, such as location, time, temperature or user identity," where relevance is described by the current task or set of objectives, that could enable a prediction of actor intentions or future events

Context Recognition: "Recognition of a previously characterised context (as described by pattern, scenario, type or template)", including possible interpretations, actions and responses, supporting a prediction of actor intentions or future events

Context vs Situation: A 'situation;' is the state of affairs in the environment relevant to a decision or an action. A 'context' is a type of generalisation that can be inferred from the situation that is in turn associated with specific decisions or actions. For example: Situation: Orange and black stripes are present in a canopy of green. Context: You are near a tiger.

Context Classification: context is thought of as a range of possible situation classifications such that we are able to classify the situation as, eg. class 1 or class 2. There may be different context sets addressing various perspectives of context.

Method

Web searchers were conducted in order to obtain definitions of primary terms, via which documents from both military and academic sources were identified. Key terms were ‘command’, ‘control’, and ‘context’.

Literature scans from the National Science Library database were generated for the sets of terms listed below, which in turn were narrowed down as described, with the final set of papers reviewed for consideration for this review.

Context awareness

- context awareness - 71534 results
- "context awareness" - 11341 results
- "context awareness" command and control - 38 results

Context recognition

- context recognition - 110779 results
- “context recognition" - 784 results
- "context recognition" command and control - 3 results
- "context recognition" military and naval studies - none
- context recognition military and naval studies - 152 results

Context as a Schema

- “Context schema” - 10,097 results
- “Context schema” - Military and naval: 9 results
- “schema decisions” - Military and Naval Science: - 13 results

Context as a Frame

- “context frame” - 48,794 results
- “context frame” - Military and Naval - 98 results
- “frame decisions” - Military and Naval - 9 results

Context as a Model

- “context model” - 789,599 results
- “context model” - Military and Naval: 1,254 results
- Filter by ‘military science’ yields 83 results

- 911 journal articles - 329 in last 5 years, 201 last 3 years
- 119 conference “Decision model”
- Military and Naval: 113 results

Decision-Making

As described in the Operational Planning Process: OPP Handbook, “the OPP is the standard method for planning major operations in the Canadian Armed Forces (CAF). It is a structured process, following a logical progression through:

- The identification and analysis of a problem;
- The development of options for solutions to the problem; and
- The translation of conceptual options into a plan that can be executed by commanders (CACSC, 2018).

The Future of Command and Control

Future command and control will be complex and integrated.

Command and Control (C2) encompasses the exercise of **authority and direction** by a commander over assigned and attached forces to accomplish the mission. The JFC provides operational vision, guidance, and direction to the joint force. (Bass & Brown, p.27) "Context in C2 operations is dynamic and includes factors such as mission, enemy, terrain (and weather), personnel, time available, and civil support" (Liu et al., 2011, p. 144).

“The Joint Operating Environment 2035 depicts an extremely **complex and interactive future environment** (such that) future operating environments will require a real time, fully networked command and control (C2) capability” to support “integration and synchronisation of actions”. (Tucholski, 2021 5; JP 3-0, 2022).

This function is becoming more integrated and challenging. “The Air Force and industry are taking the first concrete steps to turn the Defense Department's concept of **connecting battlefield sensors** and shooters from across all domains into a reality…. The technology exists. So, we need to figure out how to make it work in that warfighting ecosystem, get through the multiple levels of security [and] make sure we can trust the data and where it's coming from" (Easley, 2022, 26-27).

The eventual outcome is a **cloud-based command and control** (CBC2), an initiative demonstrated in 2023 (Gordon, 2023; Cliche, 2024). “CBC2 incorporates a large number of tactically relevant data feeds as well as artificial intelligence and machine learning to enable decision makers to maintain detailed situational awareness of the environment,” writes Cliche.

Modern Decision Science

The focus of modern decision science "is on building a framework capable to offer an effective **tool for decisions** in the field of force planning and operations planning" (Yuan and Singer, 2021), which requires a capacity to respond to dynamic and changing environments.

Classic decision-making science approaches environments as **systems** to which qualitative methods such as scenario spinning, operational gaming, or Delphi techniques, may be applied (Davis et al., 2005, p. 33).

However, in the face of increasingly complex environments, "Instead of seeking to "predict" effects on a system of various alternatives and then 'optimizing' choice, it may be far better to recognize that meaningful prediction is often just not in the cards and that we should instead be seeking **strategies** that are flexible, adaptive, and robust" (Ibid., p.46).

Some modern decision-making approaches found in the literature follow. Each of them highlights the role of context in decision making in a modern environment.

OODA Loop

John Boyd's observation-orientation-decision-action metaphorical decision-making cycle (or "OODA loop") is used, for example, to make fast and accurate decisions (Maccuish, 2012, p. 67). "Because they're developed and tested in the relentless laboratory of conflict, **military mental models** have practical applications far beyond their original context."

In the OODA model, context plays a key role in the 'orientation' stage. Orientation "involves assessing the relevance and significance of the data, understanding how it fits into the larger context, and identifying potential opportunities or threats" (Wale, 2024).

The OODA loop is recognizable in the CACSC Operational Planning Process (OPP), which recognizes five stages: initiation, orientation, course of action development, plan development, and plan review (CACSC, 2018, pp. 11-16). The OPP is informed by the Intelligence Preparation of the Battlespace (IPB) that describes the 'enemy' and the 'human terrain, which includes area, structures, capabilities, organizations, people; and events (ASCOPE) (CACSC, 2018, p. 18). For the purposes of this review, ASCOPE composes in large part the 'context' in which decision-making occurs, as discussed below.

Intent Model

David Marquet's intent-based leadership (IBL) model "is not based on the flow of power from one individual to another as in the leader-follower model, but is instead **based on a goal, or intent**, shared between individuals. A military analogy is that the leader-follower model is similar to command and control, but the IBL model is similar to mission command" (Fernandez-Salvador, 2017).

While IBL is most often discussed from a leadership perspective, as a training model it develops a learner's sense of context. "With IBL, learners gain experience in making sense of a problem. As they develop the solution to a problem, the problem begins to make sense, and learners begin to problem solve and adapt" (Duffy and Raymer, 2010, p.v).

Joint Decision-Making

Pan-domain or joint operations involve multiple levels of command and service branches, and hence entail joint decision-making. This is an area of study described, for example, in documents such as the Joint Targeting School Student Guide (Joint Targeting School, 2017) which describes the Joint Operation Planning Process (JOPP) Steps (p.7). Relevant topics include Adaptive Planning and Execution (APEX) (p. 6) and the Systems Perspective of the Operational Environment (p. 18).

The joint decision-making model builds on the OPP to create constructs like the Joint Operational Planning Process (JOPP) and Joint Intelligence Preparation of the Operating Environment (JIPOE) to enable a systems understanding of an information environment (Sylvestre, 2022, p. 14). This process is currently described in the Information Environment Advanced Analysis Course sponsored by the U.S. Undersecretary of Defense for Intelligence (JMark, 2024).

Robust Decision-Making (RDM)

Robust decision making (RDM) "is a quantitative, decision support methodology designed to inform decisions under conditions of deep uncertainty and complexity (to) help defense planners make plans more robust to a wide range of hard-to-predict futures" (Lempert et al., 2016, p. 2).

In contrast to "agree-on-assumptions" (Kalra et al. 2014) or "predict-then-act" approaches to decision-making, RDM takes an "'agree-on-decisions' approach, which inverts these steps," using "**models and data** to stress test the strategies over a wide range of plausible paths into the future." As Lempert notes (footnote 3), "The DMDU literature often uses different names to describe this inverted analytic process, including… 'context first' (Ranger et al. 2010)" (Lempert, 2019, p. 27).

Decision Support

Decision support tools are gaining acceptance to assist in the decision-making process. See, for example, the development of a software prototype Combat Resource Allocation Support (CORALS) tool (Irandoust and Benaskeur, 2015; Turgeon, 2021).

Decision Making under Deep Uncertainty (DMDU)

In cases of deep uncertainty there is not agreement on how the system works nor what future outcomes may be. Accordingly, as (Kwakkel and Haasnoot, 2019, p. 357) argue, various **representations or models** may apply. Scenario thinking, exploratory modelling and adaptive thinking are methods of preparing for alternative situation types. DMDU proposes a taxonomy of such methods (of which RDM, above, is one) that apply in different cases.

Situation Recognition

Situation Awareness

Modern decision theory requires situation awareness (SA) in order to comprehend which, if any, representation or model may apply. "Determining exactly what constitutes SA is a very difficult task, given the complexity of the construct itself, and the many different processes involved with its acquisition and maintenance" (Banbury and Trembley, 2004, p. Xiii). Moreover, "...models of SA refer to cognitive processes in general terms, but do not specify exactly what processes are involved and to what extent" (Ibid).

An understanding of the **mechanisms of arriving at situation awareness**, here called 'situation recognition', is required. "The test of situation awareness as a construct will be in its ability to be operationalized in terms of objective, clearly specified independent (stimulus manipulation) and dependent (response difference) variables ... Otherwise, SA will be yet another buzzword to cloak scientists' ignorance" (Flach, 1995, p. 155).

Computational Approach

In computer vision, "'situation recognition' is the task of **recognizing the activity** happening in an image, the actors and objects involved in this activity, and the roles they play. Semantic roles describe how objects in the image participate in the activity described by the verb" (Pratt et al., 2020, p.2).

This involves (per Wikipedia):

- "the **perception of the elements** in the environment within a volume of time and space, the comprehension of their meaning, and the projection of their status in the near future". Endsley (1995b).
- An alternative definition is that situation awareness is adaptive, **externally-directed consciousness** that has as its products knowledge about a dynamic task environment and directed action within that environment.

According to Endsley (Ibid.) expert decision-makers act **first to classify** and understand a situation, then **proceed to action** selection, for example, matching to prototypical situations in memory: Dreyfus (1981) experts, deGroot (1965) chess, Mintzberg (1973) management, Kuhn (1970) science. (p 34). This process comprehends three major approaches developed in the years following Endsley's work.

- **Schemata**, which are coherent frameworks for understanding information (information is lost but becomes more coherent and understandable). Scripts (a special type of schema) provide sequences of appropriate actions
- **Mental models**, which may be "mechanisms whereby humans are able to generate descriptions of system purpose and form" (Rouse and Morris, 1985, p. 356). Experts shift from representation to abstract codes (Ibid), for example, the situation model "provides a mechanism for the single-step 'recognition primed' decision-making" (Endsley, 1995b, p. 43)
- **Development**, whereby schemata and mental models are developed as a function of training and experience in a given environment - Holland, Holyoak, Nisbett and Thagard (1986).

As seen through the examples below, **more recent models** are based on graph analysis. "Existing situational awareness systems use prebuilt situational knowledge-based symbolic reasoning, making it very difficult to infer situational knowledge building or unexpected situations in complex, time-space dynamic environments such as battlefields" (Lee et al., 2023, p. 6057).

Examples of Situation Recognition Models

Grounded Situation Recognition, developed by AllenAI, is "a task that requires producing **structured semantic summaries** of images describing: the primary activity, entities engaged in the activity with their roles (e.g. agent, tool), and bounding-box groundings of entities" (Pratt et. al., 2020, p. 1).

Chmielewski and Sobolewski, (2019, p. 38) describe situation recognition as a "**consistent data flow** process, consisting of: data generation, data integration and filtration, data visualization, and knowledge acquisition and reasoning."

A situation awareness model with **human-machine collaboration** proposed by Meng et al. (2022, p. 1443) is comprised of a human cognitive part that includes situation perception and a machine part machine including situation recognition, where situation recognition "mainly corresponds to human's situation perception part, which is an intuitive analysis of the current situation from objective data in reconnaissance intelligence, trend intelligence and other data (p. 1444).

Baek et al. (2022, p. 308) describe a distributed **graph matching network** "to classify multiple agents based on their graph semantic information" and a "hypergraph to analyze high-order relationship between agents."

Lee et al. (2023, p. 6041) describe an architecture based on multi-modal data and **graph neural network** (p. 6042) comprising four key parts: multi-agent based manned-unmanned collaboration architecture, robust tactical map fusion technology, hypergraph based representation learning, and space-time multi layer model. “The proposed model provides collaborative intelligence-based real-time battlefield situation recognition technologies” (p. 6066).

Context

Perspectives on Context

Context is “a **complex description** of shared knowledge about physical, social, historical, or other circumstances within which an action or an event occurs… (that) does not intervene explicitly in a problem solving but constrains it” (Brézillon, 2004).

Dey and Aboud (1999) define context as “any **information** that can be used to characterize the situation of an entity. An entity is a person, place, or object that is considered relevant to the interaction between a user and an application, including the user and applications themselves” (See also Aboud, Dey, et al., 2001; See Zainol and Nakata (2010, pp. 126-127) for additional definitions along the same lines).

Winograd (2001, p. 5) argues that context is **defined by use** rather than by features. “Context is an operational term: something is context because of the way it is used in interpretation, not due to its inherent properties.” (Winograd, 2001) He offers a communication and application programming architecture using a ‘blackboard’ metaphor that supports context-aware computing.

Sato (2003, p. 1324) argues that we should represent context through “a **pattern of behavior** or relations among variables that are outside of the subjects of design manipulation and potentially affect user behavior and system performance.” He describes a three-part strategy for context-sensitivity: sensing contextual changes, re-configurable architecture, and creating and managing contexts (p. 1327).

Dourish (2004) describes an incompatibility between two views of context.

- One comes from positivist theory—context can be described independently of the actions done; the definition proposed by Dey matches this view.
- Another view can be sustained by **phenomenological** theory—context emerges from the activity and cannot be described independently.

Guarino & Guizzardi (2015, 2016) offer an account of context as a ‘scene’ such that “events emerge from scenes as a result of a cognitive process that focuses on **relationships**: relationships are therefore the focus of events” (2016, p.2) and where ‘scenes’ are whatever occurs in a certain region of spacetime.

Types of Context

Some types of context, as described in the literature:

- Activity, Identity, Location, and Time (**AILT**), (Dey and Aboud,1999)
- Context as related to **location**, nearby person, hosts or objects, as well as changes of them over time (Schilit, et al. , 1995)
- Context as tailored to the individual's **circumstances** (Brown et al., 1997). For example, this "includes the capabilities of the mobile devices, the characteristics of the network connectivity and user specific information such as emotional state, attention focus, and orientation.
- Context as **behavioural**. The Context-based Reasoning (CxBR) modelling paradigm asserts that context "contains the functionality to allow the agent to successfully 'navigate' through the current situation."
- Context **across levels** of personal, project, group and organisation. It consists of people and their expertise, information sources, informational documents and the evaluation of their relevance, and relevant pragmatic documents (Snowden and Grasso, 2000).
- Context as a **spectrum of data** described from a user perspective: computing context, user context, physical context, time context, and social context (Gu, 2009).
- Context as related to **capability** and affordances. No reference for this was found, but the representation is a natural progression from the previous perspectives.

Context-Aware Decision Support

Computational context-aware decision support (CaDS) systems are evolving from ontology-based expert systems to attribute-based neural network systems.

(CaDS) systems "consists of a **situation model** for shared situation awareness" (Feng, et al., 2009, p. 455). Such systems are intended to address information overload in military command and control, for example, in a Tactical Information Prioritization System (TIPS) (Marmelstein et al., 2008, p. 259). The aim of such research "is to enhance the decision-maker's perception, comprehension, and projection of the underlying knowledge space"(Hanratty, et al., 2009, p.1).

Dourish and Bellotti (1992, p. 107) state that awareness is an understanding of the activities of others, which provides a context for your own activity. "Awareness supposes that one is able to transform pieces of contextual knowledge into a **proceduralized** context at the current focus of attention" (Mäkelä et al., 2018, p. 7253). Key terms and "a lexicon for situation awareness is defined and the context of command in terms of organizational, operational, informational and inferential needs is examined" may be found in Thomas (2003).

To date, context-aware decision support systems have been designed along the lines of expert systems, employing "**ontology-based** decision support for military information services based on a multi-agent system" and consisting of "sensor agents to detect raw-level data, a context management agent for handling context data, an information service agent, an operational decision support agent, and user agents for maintaining user information" (Song et al., 2010, p.1).

Contemporary approaches are studying the use of **deep learning**. Early work found "the intuition of equating the template attribute weights to neural network weights resulted in a good method to learn the weights directly from observation of prior agent behaviour" (Gonzalez, 2004, p. 169) supporting Context-based Reasoning (CxBR) as "a human behaviour modelling technique that uses this approach to model human behavior in tactical situations."

Context Awareness and Recognition

'Concept awareness' denotes the capability or fact of being aware of context; by contrast, 'context recognition' describes the process or method of achieving context awareness.

Bricon-Souf and Newman (2007) describe context awareness as including:

- the ability of a program or computing device to **detect, sense, interpret**, act and respond to aspects of the environment, such as location, time, temperature or user identity
- or, from the perspective of **adapting application** to context, it is the ability of applications to examine the computing environment and react to the dynamical changes such as the location of user, the collection of nearby people, hosts, and accessible devices, and adapt their behavior based on the context of the application and the environment
- Dey (1999): "A system is context-aware if it uses context to **provide relevant information** and/or services to the user, where relevancy depends on the user's task."

A variety of context recognition mechanisms may be employed. For example, in a survey of research on context recognition in surgery, Pernek and Ferscha (2017) identify the following:

- **Environment** tracking - use of "pluggable monitors and devices that can be connected and used to infer surgical workflow" (p. 1722)

- **Kinematic** tracking - “focused on tracking the location of surgical instruments or quantifying hand movements of surgeons” (p. 1723)
- **Video tracking** - “recognize actions from intra-body video images” (p. 1723)
- **Cognitive state** context - through eye-gaze, skin response, heart-rate, force (p. 1724ff)

The predominant mechanisms employed were **machine learning or neural network-based** pattern recognition algorithms. For example, Radu et al. (2018) study “the benefits of adopting deep learning algorithms for interpreting user activity and context as captured by multi-sensor systems” (p. 157.2). Similarly, Billones et al. (2018) discuss the use of deep learning for vehicular context recognition. Alajaji et al. (2020) “propose DeepContext, a deep learning based network architecture for recognizing a smartphone user's current context.”

Context as schema

The general sense of a schema is as a semantic representation consisting of a form of representation as a generalisation combined with **elements or blank spaces** that are filled by concrete particulars to constitute an instance of the schema (Bartlett, 1932, Corcoran and Hamid, 2016).

Context may be thought of as “a mental **codification of experience** that includes a particular organised way of perceiving cognitively and responding to a complex situation or set of stimuli” (Merriam-Webster, 2024). There are senses of ‘schema’ in logic, psychology, computer science. Schemas may be thought variously as:

- consisting of i) set of words and blanks, ii) mechanism for filling blanks, or
- consisting of i) individual concepts, ii) mechanisms to connect concepts (Gal'perin, 1989, p. 65)
- consisting of scripts (Schank and Abelson, 1977)

Schemas are recognized to be constantly changing. Bartlett’s “concept of schema emphasises the dynamic and evolving nature of these **cognitive constructs**, which continuously adapt as we encounter new information” (Main, 2023).

Schema Development

Depending on the discipline or perspective, schema development may be described as ‘orientation’, ‘view’, or ‘case-based’.

‘**Orientation**’ is one of the steps in the OODA loop, discussed above. Orientation is depicted as “a schema to elucidate the role of human cognition (perception, emotion, and heuristics) in defense planning in a non-linear world characterized by complexity, novelty, and uncertainty” (Johnson, 2023, p. 43).

In IT and database development for systems such as JBI-IM (discussed above), context is represented as the development of various '**views**' representing various ways to display underlying data schemas. For example, "The Department of Defense Architecture Framework (DoDAF) "includes augmenting the underlying data schema… and evaluating the implications of the additional viewpoint" (Handley et al., 2016, p. 415).

Case-based classification "retrieves and reuses decisions based on training data" to support, for example, to support automated web service discovery and brokering (Ladner et al., 2007).

Schema Activation

Schema 'activation' is the deployment or **retrieval of a schema** to be applied or descriptive of a particular situation, and is often depicted as a cognitive process. For example:

"Activating schemata and training students to use reading strategies are both generally effective in reading comprehension skills" (Cho and Hyun, 2020, p. 49).

"Through schema activation, **judgments are formed** based on internal assumptions (bias) in addition to information actually available in the environment" (Worthy et al., 2024).

Schema Change

Schemas may change either through **accommodation or assimilation** of new data through either a top-down or bottom-up process.

The Composition Modeling Framework (CMF) is a standards-based information engineering methodology that tackles existing and emerging Department of Defense (DoD) interoperability problems using a bottom-up approach (Staskevich et al., 2007).

"When existing schemas change on the basis of new information, we call the process accommodation. In other cases, however, we engage in assimilation, a process in which our existing knowledge influences new conflicting information to better fit with our existing knowledge, thus reduc(ing) the likelihood of schema change" (Worthy et al., 2024).

Context as frame

A 'frame' is most generally thought of as an **organisation of experience** (Goffman, 1974) and in this sense more of a cognitive or psychological construct than semantic. It is an interpretation of reality "that puts the facts or events referred to in a certain perspective" (Morasso, 2012, p. 5).

From a more computational perspective, Minky's (1974) is an elaboration of the schema. "Here is the essence of the theory," writes Minsky. "When one encounters a new situation (or makes a substantial change in one's view of the present problem) one selects from memory a structure called a Frame. This is a **remembered framework** to be adapted to fit reality by changing details as necessary."

In their consideration of choice theory in uncertain conditions, Tversky and Kahneman argue that "the normative and the descriptive analyses of choice should be viewed as separate enterprises" (1986, p. s275) with framing describing the former (for example, where someone is risk-tolerant or risk-averse). Lakoff (2010, p. 71) describes frames as "structures (that) are **physically realized in neural circuits** in the brain. All of our knowledge makes use of frames, and every word is defined through the frames it neurally activates."

Examples

The concept of a frame is at once less formal and more detailed than the schema, and consists not only of a generalised description of a situation or collection of data, but also objectives, expectations or values. These are illustrated with the following examples:

- "The common good" in diplomacy in military affairs (Karadag, 2017).
- "the frame of arms control" in distribution of verification resources (Avenhaus and Canty, 2011).
- "Luttes de sens, cadrages et grammaire lexicale en contexte révolutionnaire" (Struggles for meaning, framing and lexical grammar in a revolutionary context) (Rey, 2020).
- "Framing war: Public opinion and decision-making in comparative perspective" - "uses the recent war on Iraq as a case study, focusing on the elite and media framing of this event in order to examine the interaction between the political elite and the mass public" (Olmastroni, 2014).
- "the analysis of the strategic culture of Hungary is approached from a perspective that will frame the cultural and ahistorical view of the international policy of the neorealists with its own cultural and historical dimension" (Jeremić, 2021, p. 51).
- "identifying four related concepts that help frame how a COP may improve an organization's efficiency and effectiveness: effectiveness-based measures, decision rights,schwerpunkt, and neutral integrators" (Pyles et al., 2008, p. 5).

Frame Vs Framework

A frame should be distinguished from the related but distinct concept of the 'framework'. The latter is not a cognitive or psychological construct, but rather a method or process designed to explain, guide or improve decision-making (for example, Elgoff and Smeets, 2023, p. 502). In this context, a framework is best viewed as a decision-making or design tool (see 'Decision-Making, above).

Context in metaphor

Metaphor is a powerful instrument for creating and representing frames in cases where literal representation is insufficient.

“The concepts that govern our thought are not just matters of intellect,” writes Lakoff (1980, p. 3). The metaphor ‘argument is war,’ for example, “is one that we live by in this culture; it structures the actions we perform in arguing.” Similarly, Taylor (2008, p. iii) writes, “The conception of literal meaning adopted by both semantic and pragmatic metaphor theorists, which roughly indicates an adherence to a lexical authority and conventionally accepted grammar, is far too limited in scope to account for what is generally taken to include literal meaning in the use of language.”

Metaphor may be thought of “as an eminently **cultural linguistic phenomenon**”, however, “There are several different ways of thinking about the nature of context in metaphor production that is not necessarily cultural” (Kövecses, 2017, p. 307). Metaphors both define and are defined by context.

“The purpose of metaphorical framing is to convey an abstract or complex idea in **easier-to-comprehend** terms by mapping characteristics of an abstract or complex source onto characteristics of a simpler or concrete target” (Wikipedia, 2024). It “tends to illuminate certain aspects while obscuring others” (Norscini and Daniela, 2024, p. 14). Thus a complex phenomenon is rendered more concrete.

Context as model

Context as a model is predominantly found in the form of a ‘**context model**’. “Context models are used to illustrate the operational context of a system - they show what lies outside the system boundaries” (Kurkovsky, 2024; Sommerville, 2015, Chapter 5).

In an ontology, a context model helps define a subject using a semantic analysis of information related to the subject. Wang et al. (2004, pp. 18-19) describe several informal context modelling approaches and present a formal context ontology. A software system context model “explicitly depicts the **boundary** between the software system and its external environment” (Johnston, 2021). A physical system context model may define an **environment** for a software simulation, for example, digital twin (Sahlab et al., 2022, p. 463).

Large language models (LLM) also have mechanisms to define context. For example, a ‘**context window**’ defines the request space for an LLM. A recently released version of Google Gemini defines a 1 million token context window that allows it “to understand up to one hour of video, 11 hours of audio, over 700,000 words (so it could read, digest and answer questions about Tolstoy's War & Peace) or over 30,000 lines of code” (Pichai, 2024).

Types of Model

It is beyond the scope of this review to identify and define the full scope of models and model technology; the typologies offered below provide a sense of this scope with respect to context.

Process Models:

- Mathematic - for example, “mathematical models of combat activities and combat means of destructions, and their development paths of the use of troops in the process of preparation” (Mikayilov and Bayramov, 2019, p. 156)
- Deterministic - for example, to define ship speed optimisation from the perspective of cash flow (Beullens et al., 2023).
- Stochastic - for example, decision support in a dynamic environment such as a wildfire (Roozbeh et al., 2021).
- Forces – for example, Porter’s Five Forces (Porter, 1979).
- Neural Network Model - a simplified model of the operations of a human brain involving creation and activation of patterns of connection (IBM, 2021).

Business Models:

- Logic Model - a mechanism for describing inputs and outputs for translation of business data into outcomes or benefits. For example, Paul et al. (2015, p. 17).
- Mental Model - “ an overarching term for any sort of concept, framework, or worldview that you carry around in your mind.” Clear (2024) provides a pretty good list. Boyd (1973) describes forms of mental models as patterns or concepts in his description of OODA (described above).
- Case - a specific business-focused description of a business situation,either for study after the fat or that “puts a proposed investment decision into a strategic context and provides the information necessary to make an informed decision” (TBS, 2009).

Computational Models:

- Data Model - a representation of data structures, may be a schema (see above) or ontology, depicted textually (XML, JSON) or as a diagram (Entity Relationship (ER) or Universal Modelling Language (UML)). See for example ‘context data model’ (Ceri et al., 2007) or ‘contextual design model’ (Holtzblatt and Beyer. 2017).
- Simulation - for example, “The use of modeling and simulation offer a better understanding of the concepts and solutions for commander's decision making” (Cîrciu et al., 2010, p. 93; Connable, et al., 2014).

- Multi-Objective Optimization - for example, a multi-objective model for hub location and cost sharing (Mrabti et al., 2022).

Validation

Models are intended to serve as representations of processes, data or physical environments. As such, unlike schemas or frames, models have a unique **requirement** of validation. The following terminology is employed:

- **Verification**: The process of determining that a model implementation and its associated data accurately represent the developer's conceptual description and specifications.
- **Validation**: The process of determining the degree to which a model and its associated data provide an accurate representation of the real world from the perspective of the intended uses of the model.
- **Accreditation**: The official certification that a model, simulation, or federation of models and simulations and its associated data is acceptable for use for a specific purpose. (All quoted from AcqNotes, 2024; DoD 2008; Owen, and Chakrabortty, 2022).

In a wider context, other criteria and terminology may be used to evaluate models, for example, model fit and measurement invariance (Goldammer et al., 2024).

An 'inference to the **best explanation**' model minimally consists of the following (Quoted from Rast, 2023, p. 3):

- Abduction: The generation of candidate hypotheses and theories.
- Epistemic value: One or more epistemic values that order theories.
- Theory evaluation: An aggregation operation that takes orderings of theories and yields an overall ordering.

Theory evaluation may consider 'epistemic virtues' such as simplicity, paucity, or commensurability.

Composability

'Composability' is defined as "the capability to **select and assemble components** in various combinations to satisfy specific user requirements meaningfully" (Yilmaz, 2004, p. 149).

Composability assumes greater importance in multi-facted and complex environments. "A defining characteristic of composability is the ability to combine and recombine components into **different systems for different purposes**. Ability to locate and reuse existing models in new experiments and application scenarios is critical as a first step to compositional construction of complex simulations" (Ibid.).

Yilmaz (2004, p. 141) describes a “strategy to improve **reuse and composability** via (1) separation of the concept, content, context, and simulator in simulation modeling and (2) explicit characterization and distribution of context information to facilitate systematic model qualification and model understanding for composition.”

Data, Information and Capability

This final section considers the topics of data, information and capability from the perspective of the challenges they create to the conception of context in pan-domain command and control.

Data

Data constitutes the raw material collected or assembled to enable context recognition, and may be generated by human observation or sensor readings. There is significant literature on data, including the topics of data and theory (Andrews, 2023), data and instrumentation (for example, Ackerman, 2014), data management, data literacy and data ethics.

Contextual factors often shape data. For example, a cost and benefits analysis of body-worn camera deployments may be undertaken from the perspective of cost savings, in which ase data may be collected on the equivalent in police salaries, or from the perspective of transparency and accountability, in which case data may be collected on incident reduction (Wexler, 2018, p. 17).

Similarly, data collection may reflect existing prejudices or unstated expectations. For example, “When data teams are primarily composed of people from dominant groups, those perspectives come to exert outsized influence on the decisions being made—to the exclusion of other identities and perspectives. This is not usually intentional; it comes from the ignorance of being on top. We describe this deficiency as a privilege hazard” (D'Ignazio and Klein, 2020 , p. 28).

Information

Information represents a processing of data into actionable form, for example, the reduction of uncertainty among possible states (Dretske, 1981, p. 12). “Advances in information technology are increasing the reach, speed, and effectiveness with which humans acquire, process, and transfer information” (Mulgund and Kelly, 2020, p. 15).

“Specific uses of information to affect perceptions, attitudes, and behaviors include:

- Informing domestic and international audiences through the release of accurate information to put operations in context
- Influencing relevant actors… to change or maintain behaviors

- Attacking and exploiting information, information networks, and information systems" (Ibid., p. 16, citing Joint Publication 3-0,3).

Accordingly, "The joint force must understand how to manipulate and leverage information and the inherent informational aspects of activities to send deliberate messages" (Ibid., p. 15).

Capability

Actionable information is based on "information exchange and persistence capabilities that support tailored, dynamic, and timely access to required information, enabling near real-time planning, control, and execution for DoD decision making" (Clark et al., 2005, p. 285). Key to this function is interoperability, typically within "a publish and subscribe paradigm whereby edge users are notified of and presented with new information as it becomes available."

Capability is essential to information management. "The AFWIC's response envisions strategic dominance through a persistent distributed networked C2 capability that enables global multidomain operations 'within seconds and minutes.' This persistent network requires the proliferation of sensing and communications hardware" (Tulchoski, 2021, p.5)

Modern information-centric environments are the subjects of information warfare. In addition to the obvious physical constituents, successful information warfare requires "understanding culture, history, local political dynamics, the interactions of different players, and the need to forge cohesive communication plans at the strategic, operational, and tactical levels matters more than ever to commanders and operators" (Farwell, 2020).

Data and information literacy are essential components of both context-aware command and control and defense against information warfare. Yet "How well human war fighters and decision-makers will utilize these technologies is not so clear. Empirical evidence suggests more information often has negative effects on decision-making, resulting in inferior outcomes" (O'Shaughnessy, 2020, p. 74).

Discussion

Decision-making in any complex or dynamic environment requires broad access to timely and accurate information, but the meaning of any piece of information will be influenced by contextual factors. Context awareness is therefore essential in order to access information.

Context recognition, which is the mechanism that enables context awareness, has traditionally been represented as the presentation and selection of one or more models, frames or schemas from an array of predefined and pre-learned alternatives.

It is understood that some degree of classification is required in order to identify, rank and select from alternative courses of action; we could say we can classify a context but we can only describe a situation. A classification is in an important sense an interpretation of a situation, and as such, both defines and is defined by context.

Modern decision-making appears however to be passing over the step of situation recognition and advancing directly to action or decision; because of the complexity of contemporary information environments it is less and less likely that one, or any, predefined and pre-learned model can be identified. Such a case is defined as ‘deep uncertainty’.

Graph and neural-network models hence proceed directly from data and information to decision. The process of frame, schema or model-making is allocated to the neural network, which instead of depending on human-constructed models bases recommendations on the stored relations or connections between thousands or tens of thousands of features or parameters.

Keeping - as we must - a *human* at the key interface between data and decision requires understanding and development of a similar capability in human commanders, meaning less of a reliance on explicitly described frames, models and schemas (except as heuristic devices) and more on acquired perception and intuition through practice and on-site experience.

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Task Analysis

This section describes the task analysis that was performed in order to better understand the pan-domain command and control task. This step is crucial in order to develop the next ones.

Method

In order to complete the task analysis, we employed two data collection techniques: we reviewed documentation from the Department of National Defence (DND) and conducted semi-structured interviews of DND commanders at the Colonel level.

For documentation review, we used four documents [1, 2, 3, 4], in addition of being informed by the results of the previous literature review. The first document, published by DND is the most recent one (2022) and provides the latest definition of Pan-Domain.

For the semi-structured interviews, five DND commanders at the colonel level were recruited by email on a voluntary basis out of a pool of eight potential name and emails provided by DND management.

Participants

For this analysis we conducted five semi-structured interviews, with a total of five different consenting participants from DND. All of them are currently commanders at the colonel level. The duration of the interviews was limited to one hour.

All the participants were interviewed during their normal work hours and were thus being paid to participate in the study. This study, which involves human subjects, has been approved both by Defence Research and Development Canada (DRDC) and the Research Ethics Board of the National Research Council Canada (protocol 2023-181), which follows the Tri-Council Policy Statement [5].

Recruitment

The names, roles and email addresses of potential recruits were provided by the Canadian Joint Warfare Centre's management. Email invitations were sent to the prospective participants in several rounds along with information about the project and the consent form. Since the recruitment process was conducted online, participants returned a signed consent form via email or acknowledged they have read it and consent to participate to the study. Five participants consented to participate in the study, out of six invitations.

Procedure

Our objective was to understand the tasks performed by commanders, including the conditions under which pan-domain command and control is performed, and the order in which they performed the tasks. All the interviews were conducted by using the Microsoft Teams videoconferencing application. Nothing was electronically recorded and a team of two people interviewed the participant during each session, generally with one asking questions and the other one taking notes. For data representation, we used a hierarchical task analysis [6] method inspired by MAD [7] and its enhanced version, MAD* [8].

Results

This task analysis revealed that there are three levels of command and control, namely, strategic, operational, and tactical levels. Figure 1 below illustrates the initial task model built based on the results of the interview.

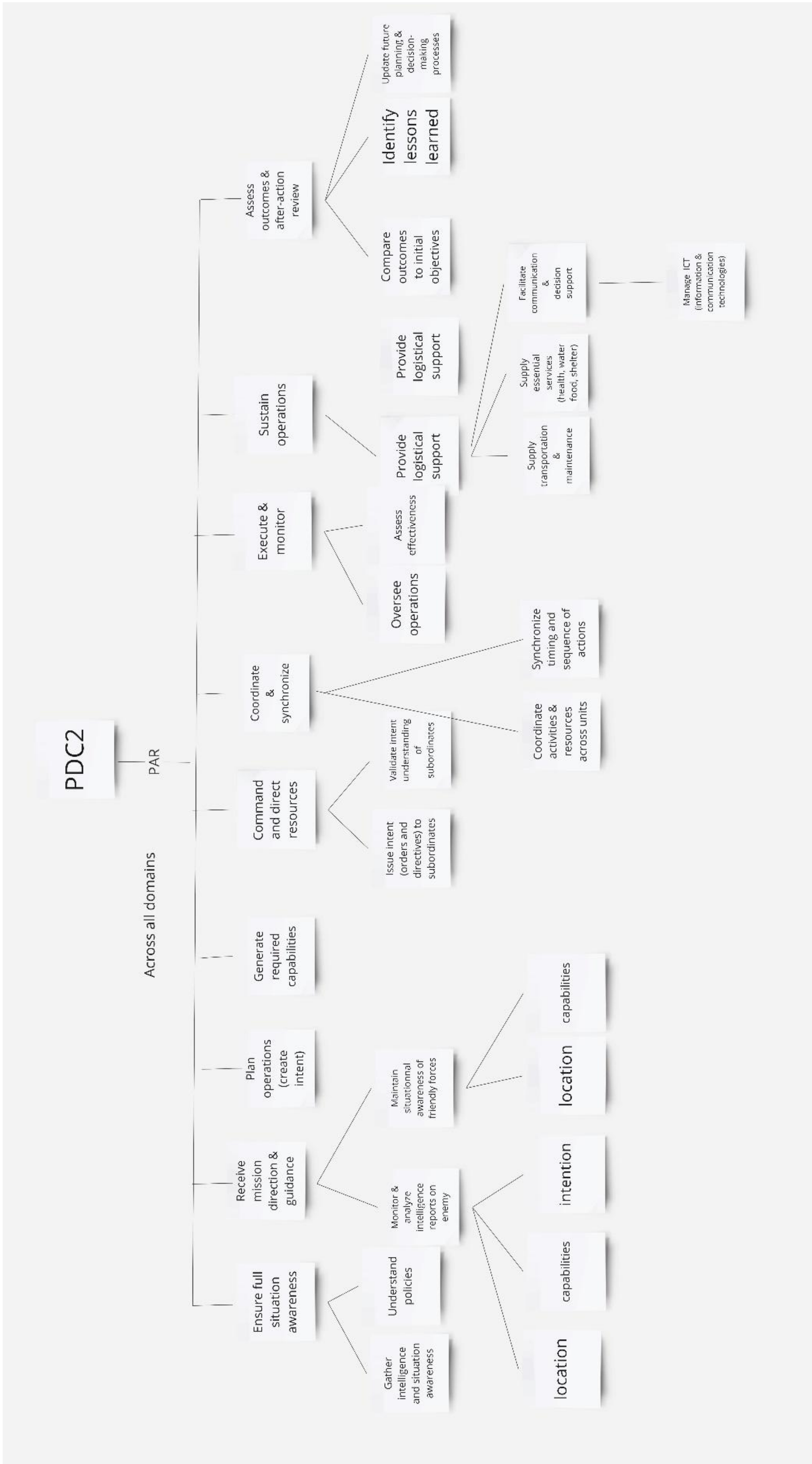

Figure 1. illustration of the PDC2 task model using a hierarchical task analysis

Now, given that all tasks and subtasks are executed in parallel, a second version of the task model was built, based on circular network diagram. The result is illustrated at Figure 2.

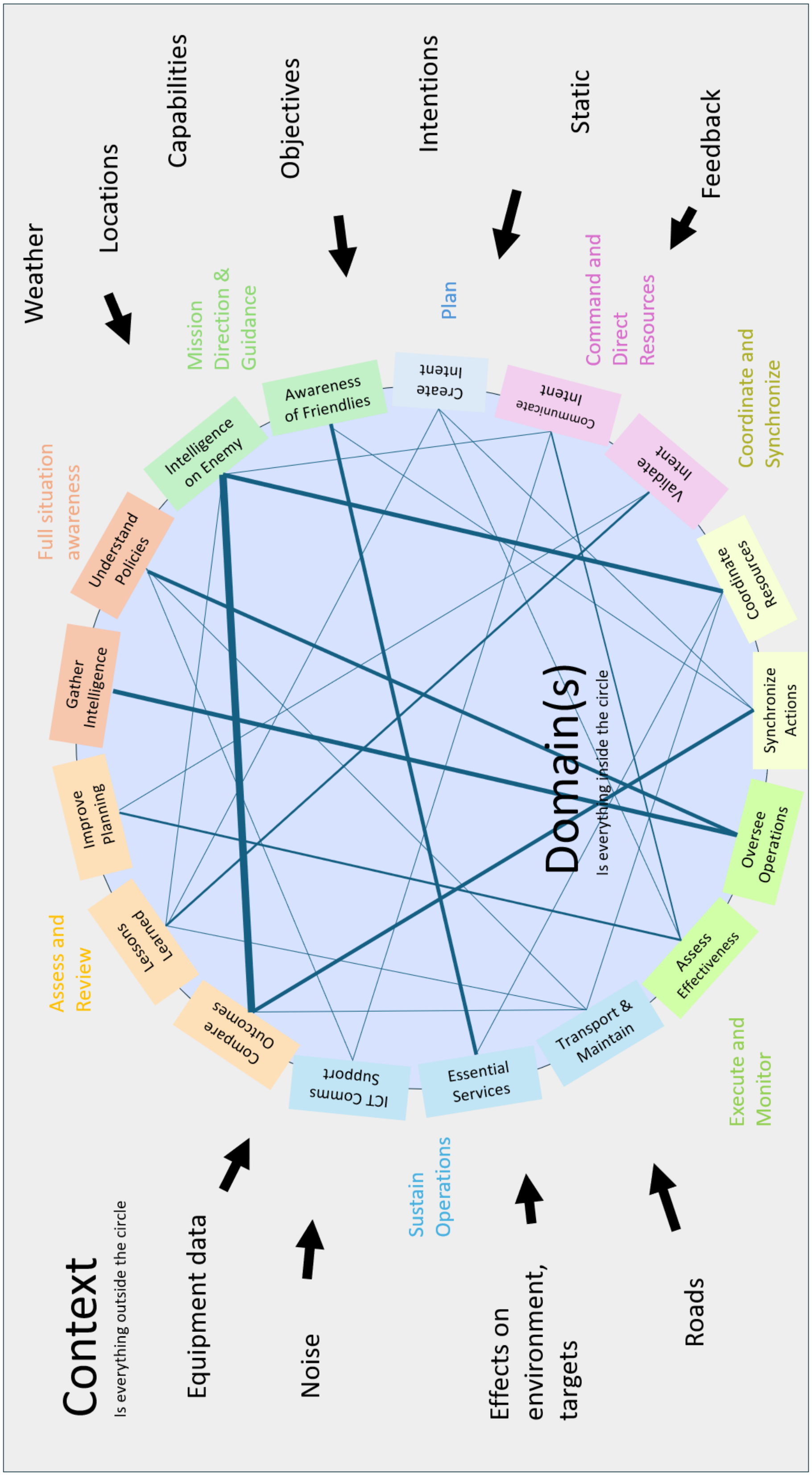

Figure 2. illustration of the circular task model

Explanation of the Circular Task Model

Overview

This diagram represents the circular task and decision model for a pan-domain command and control environment (PC2).

The area of the blue circle represents activity within the domain(s) of activity, which is to say, that which is subject to command and control. The white outer area represents the context in which that activity takes place, which is to say, that which is not directly subject to command and control.

Boxes

The boxes around the edge of the circle represent specific task domains and are the topic of this task model. The colouring of the boxes and coloured text represent categorizations of different task domains, to make it easier to understand the nature and grouping of the task domains.

Each task domain represents a specific type of activity identified in the course of this research project, either through the literature review, or interviews with commanders, or (more frequently) both. They may be considered in more or less detail, depending on whether we take a strategic, operational or tactical perspective.

Unlike other types of task model (for example, models based in an OODA loop, or even models based in systems analyses, described in the literature review) the performance of tasks within the task domains does not proceed sequentially. That is to say, at any given moment in a PC2 environment, all task domains will be operational simultaneously.

Lines

Though all tasks operate simultaneously, we can observe sequences of activity from one moment to the next. A task performed in one moment may influence another task performed in the next moment. The lines connecting the boxes represent this influence. For example, data obtained as a result of 'intelligence on enemy' may have an impact on a subsequent task 'coordination of resources'. These influences happen in real time, and can happen in no particular order, which can create the appearance of a dynamic and chaotic environment, which is the type of environment being described in the literature today.

The lines in the diagram offered here do not represent any actual measured influence of one task domain on another. Currently, we offer them only as examples of the multi-faceted simultaneous influences from one task domain on another that *may* exist. The intent, though, is to identify lines of influence based on observed and measurable impacts.

The lines capture some useful elements of analysis. The existence of a line identifies the observed instance of an influence from one task domain to another; this influence may be characterized as one condition or set of conditions causing one effect or set of effects in the connected domain. The width of the line represents the significance or strength of the influence, and should correspond to a measurable effect scale.

From such observations specific sets of impacts of one task on another may be constructed as collections of specific sets of lines between task domains. For example, the OODA loop, which may be observed in practice, may be depicted as a circle diagram consisting of four boxes (Gather Intelligence, Create Intent, Communicate Intent, Oversee Operations) with a line connecting each of these in sequence. We can refer to a specific formulation such as this as a 'task profile' within the overall task model. Development of these task profiles may be a subject for further research.

Context

As described previously, in this PC2 task and decision model, 'context' is everything that lies outside the domain of command and control. Context may be described in the first instances by considering a range of such factors, including sensor readings and equipment data, weather, locations of targets, overall strategic intent and political direction, roads and geography, effects of previous actions, and the like. The grey arrows represent the influence that context, thought of generally, may have on specific task domains. Any task domain, therefore, may be influenced by any other task domain, and by context (which may be described in terms of contextual factors).

Though we have not specified specific contextual effects on specific task domains, the description of such effects would constitute part of a description of a context profile.

Situation Types

The whole (PC2 domains and context) at any given point in time may be denoted as a 'situation'. In this model, PC2 is determined by 'situation awareness', and the required capacity for effective PC2 may be described as 'situation recognition'.

In the literature review, we identified a number of characteristic forms of context recognition, when we now here extend to describe types of situation recognition as well. In this sense, situation recognition is the identification of a specific situation as being an instance of a type of situation. For example, on seeing a specific situation where people throw balls and run around a diamond, a person will recognize a situation type, 'baseball game'.

In our literature review we also noted that situation types may be described in various ways; we described schemas, frames and models. These represent the semantical, psychological and physical aspects of situation types generally. We can say here specifically that a situation type is based on a physical environment (which is described in the task model) that is recognized as a specific type (which is a psychological act) and then communicated to other members of the PC2 team (which constitutes the semantical characterization.

Situation Recognition

As stated above, any task domain may be influenced by any other task domain and by context. These together form the situation. PC2 with respect to any particular task domain, or any set of task domains, therefore, requires situation recognition, as described here.

We mentioned above that a specific set of influences among task domains can be described as a 'task profile'. Similarly, we can characterize individual situation types as 'situation profiles'. A situation profile, therefore, represents a set of influences of specific contextual factors on task domains, and of those task domains on each other (which we would represent on the task model diagram as a set of lines connecting the relevant boxes, which depict actual measured influences of one element upon the other).

Accordingly, situation recognition may be characterized as the classification of a situation (typically by a commander) as one or another situation type, which is in effect a summary term describing a combination of physical, psychological and semantical factors characterizing the context and PC2 environment impacting the performance of a specific task domain.

Advancing the Circular Task and Decision Model

The Task and Decision Model presented in this report represents the results of research including a review of relevant literature and interview with commanding personnel in the Canadian Armed Forces. It therefore represents the task and decision model in the abstract. Further research would be needed to test the model and validate its effectiveness.

Task Domains

While interviewees expressed confidence in the list of task domains presented in the model, empirical validation would determine whether the descriptions and categorizations are complete and accurate. Validation would also help identify appropriate granularities of description for different levels of command. Further research would obtain broader confirmation of the list of task domains, and comparison with artificially-generated task domain categorizations based on a body of knowledge (for example, texts of after-action reports) would identify whether this list represents all and only task domains relevant in PC2.

Influences

Represented by lines in the model, influences of any given task domain on another remain undocumented. Two lines of investigation exist. First, what features of influences are relevant and how are they described? For example, we may consider such variables as weight (how important is the influence to the task?), activation threshold (what strength or frequency of influence impact the task?), values (how do different types of influence impact the task?), among others. Second, what sets of influences (characterized above as a ‘task profile’) are either (a) present in actual data (as characterized by, for example, after-action reports), and (b) recognized as such by commanders. Description of the influences and the weights of the lines constitute avenues for further research on this model.

In other words, various task profiles may represent patterns of activity that are commonly recognized (and often informally named) by commanders. These patterns may represent both functional and dysfunctional task profiles, for example, a specific type of mission profile such as ‘hostage retrieval’, or a characteristic failure such as ‘communication breakdown’. The research question is thus (a) is there a way of describing such patterns? And (b) are these patterns recognized? And (c) can we provide machine learning assistance to support pattern recognition?

Context

Very similar statements may be made about context profiles (ie, combinations of schemas, frames and models recognized as such by commanders) as have been made about task profiles. The same three research questions may also be asked of context profiles, and then, by considering task profiles and context profiles in combination as situation profiles.

The significance of providing machine learning assistance to support pattern recognition is evident in the apparent complexity of situation profiles. Based on our assessment thus far, any given situation profile will be composed of several dozen distinct factors, including the 17 task domains we have identified, plus an uncounted number of context domains, and all the possibilities within each domain. Additionally, a given situation profile may not consist of an exact set of factors, but rather, a non-specific set of factors, and also in environments where some characteristic factors are not present or are hidden from view. Machine learning and artificial neural network analysis support recognition based on partial representation (the way, for example, we can identify an animal as a cat after having seen only its head). Highly trained and experienced commanders are capable of recognizing characteristic patterns in the task and context domains, but machine learning support may assist less experienced commanders, and may help experienced commanders communicate what led them to recognize a particular pattern.

Incremental Development

It is recommended that the task and decision model described here be tested in limited increments.

For example, it was suggested during the interviews that ‘lessons learned’ reports are always authored, but less frequently consulted. The circular task and decision model, if applied in this context, would receive as input a body of ‘lessons learned’ reports. Analysis of these reports could result in the creation of a number of ‘lesson profiles’, that is, characteristic patterns of lessons learned. The method of analysis would then be tested by (a) comparison with sets of types of lessons learned produced by experienced commanders, and (b) assessment of the relevance of a machine-assisted presentation of past lessons learned prior to undertaking a new action based on that categorization.

Any number of task and situation profiles could be tested in this way. For example, any given action will require the selection and provision of different type of equipment. We can contemplate various characteristic sets of equipment required for, say, an amphibious landing, as compared to a forest fire rescue, as compared to a coastal patrol. They circular task and decision model would accept as input data from previous reports of equipment selections and related data, and then when presented data describing a new situation, would recommend one or more ‘equipment profiles’ appropriate for that action.

Evaluation of such tasks would be based not only on whether the machine assisted recommendations matched human recommendations, but also whether machine assisted recommendations recognized characteristics or nuances that may have been below the human commander’s threshold of recognition.

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Possible Roles of Digital Technologies for Context Awareness and Context Recognition

This section explores how digital technologies could play a role to integrate context awareness and context recognition in assisting commanders in the execution of pan-domain command and control tasks.

Based on the interviews, several possibilities have been identified. They are listed here in no particular order:

- Mission planning
  - The ramp-up., building the team, information about the locations in the planning space.
- Supporting and maintaining the welfare of the troops
  - Measuring how troops are doing, physically and mentally by using psychometrics questionnaire/coaching and/or biometrics sensors.
  - An analysis could be made, for instance, by comparing to baselines the day before something awful happened.
- Automated integration of lessons learned into decision making
  - Combine 'lessons learned' documents into a database.
  - Train a neural network (AI model) on them.
  - Present details of new operation to neural network.
  - Use the neural network to rank the lessons learned documents in terms of similarity to the current operation and present the top ones.
  - Optionally: summarize relevant lessons learned from all documents.
- Real-life mission data reporting
  - E.g. fuel expenditures, ammunition, water, food - all this is challenging - not just stores but where they exist in outer areas off operation. E.g. up north, where runways are, where fuel and waterways are.
  - Noting the impact of supplies on a community (eg, drawing on limited resources in a community).
  - 'Contested logistics' - we can't assume we can just keep flying food and water etc. because our adversary would try to disrupt the supply chain - so more and more plans consider adversary capability and internet, so we need to try to counter that. Adversaries could, for instance, launch a cyber-attack and shut down a port. AI would really help with strategic lines

of communication. AI would need to understand potential vulnerabilities. A commander planning a mission can't just assume all of these will be available.

- Reporting on available communication spectrum
  - Knowing within a few clicks which communications system would work, were they degraded, to what latitude will they work, etc.
  - AI could help assess what's going to work and where. Right now, it's all manual. Automating development of a PACE plan (Primary, Alternate, Contingency and Emergency).
- Targeting using AI
  - Using a trained AI on imagery or other sensors data (e.g. radar, sonar, or anti-aircraft system, etc.) to quickly identify targeted objects and then signal to commanders objects of interest or concern. Allowing the AI to be your eyes, while keeping a human in the loop. Reduce it to a map where you can just see where they are.

The topics listed above will need a deeper evaluation of their scope, priority, and effort level. Additionally, we choose to include here topics that were identified as important and promising avenues, which include some that may not correspond to current research areas and priorities of NRC-DT.

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13a. ABSTRACT (when available in the document, the English version of the abstract must be included here.)

The pan-domain command and control decision making process takes place in an increasingly dynamic and complex environment. Today's domains include not only the traditional domains of land, air and sea, but also digital age domains such as space, cyber and information. The speed at which the environment changes has increased and commanders require new ways to adapt to changing contexts in which they exert authority and implement mission intent.

This technical report presents a scoping study in which the changing dynamics of context recognition and awareness are mapped and a command and control task model based on this mapping is outlined. It is divided into three main sections. The first section reports the results of a literature review on context awareness and context recognition, providing an overview of key terms and review the state of the art on the topic. Context recognition is described as a process of representing complex environments as characteristic schemas, frames or models, and identifies the roles these abstractions play in decision-making in terms of data, information and capability. The second section presents the results of a command and control task analysis based on both the literature review and interviews with Canadian Forces command personnel. A circular graph-based task model is proposed depicting the multiple simultaneous influences of task domains on each other, as an effect of context, and as a basis for context recognition. Finally, the third section suggests avenues of future research that may expand our understanding of context recognition and identify how the use of digital technologies such as artificial intelligence may assist commanders in context recognition and decision-making tasks.

13b. RÉSUMÉ (when available in the document, the French version of the abstract must be included here.)

Le processus de prise de décision en matière de commandement et de contrôle pan-domaine se déroule dans un environnement de plus en plus dynamique et complexe. Les domaines actuels comprennent non seulement les domaines traditionnels que sont la terre, l'air et la mer, mais aussi les domaines de l'ère numérique tels que l'espace, la cybernétique et l'information. La vitesse à laquelle l'environnement change s'est accrue et les commandants ont besoin de nouveaux moyens pour s'adapter aux contextes changeants dans lesquels ils exercent leur autorité et mettent en œuvre l'intention de la mission.

Ce rapport technique présente une étude exploratoire dans laquelle la dynamique changeante de la reconnaissance et de la connaissance du contexte est cartographiée et un modèle de tâche de commandement et de contrôle basé sur cette cartographie est esquissé. Il est divisé en trois sections principales. La première section présente les résultats d'une analyse documentaire sur la prise de conscience et la reconnaissance du contexte, en fournissant une vue d'ensemble des termes clés et en examinant l'état de l'art sur le sujet. La reconnaissance du contexte est décrite comme un processus de représentation d'environnements complexes sous forme de schémas, de cadres ou de modèles caractéristiques, et identifie les rôles que ces abstractions jouent dans la prise de décision en termes de données, d'informations et de capacités. La deuxième section présente les résultats d'une analyse des tâches de commandement et de contrôle basée à la fois sur l'analyse de la littérature et sur des entretiens avec le personnel de commandement des Forces canadiennes. Un modèle de tâche basé sur un graphe circulaire est proposé pour décrire les multiples influences simultanées des domaines de tâches les uns sur les autres, en tant qu'effet du contexte, et en tant que base pour la reconnaissance du contexte. Enfin, la troisième section propose des pistes de recherche futures susceptibles d'élargir notre compréhension de la reconnaissance du contexte et d'identifier comment l'utilisation de technologies numériques telles que l'intelligence artificielle peut aider les commandants dans les tâches de reconnaissance du contexte et de prise de décision.