2016 IEEE International Multi-Disciplinary Conference on Cognitive Methods in Situation Awareness and Decision Support (CogSIMA)

A Dynamic Agile Process Model for Situational Awareness:
A Machine-Understandable, Fractal-based, Data-driven Approach

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***Abstract*—*This position paper describes how a proposed Dynamic Agile Process Model (DAPM) can be a useful representation of situational awareness. The traditional definitions of situational awareness are highly conceptual and text-based, intended for human consumption, so a simpler, more specific machine-understandable definition is needed for computer processing. At its simplest, the authors suggest that situational awareness can be considered the intersection of processes. If the processes can be represented effectively and efficiently in a computer representation, then so can situational awareness. The Dynamic Agile Process Model (DAPM) has certain characteristics, including both static and dynamic aspects, as well as fractal characteristics such as self-similarity, complexity built from simplicity, and optimized information flow, which seem to match the similar characteristics of situational awareness. Using this process model, situational awareness can be represented in a manner amenable to machine processing for applications such as planning, training, command and control, intelligence, surveillance and reconnaissance, and after-action analysis. The authors are beginning to explore enabling situational awareness in smart avatars using this model for these applications in the SPAWAR Systems Center BEMR lab: Battlespace Exploitation of Mixed Reality. For more information or to participate or join the Advanced Exploitation of Mixed Reality (AEMR) Community of Interest, please send an email to BEMR@spawar.navy.mil*

Keywords- Situational Awareness, Process Model, Fractal, Agile, Machine Understandable, Training, Decision making, information flow, standards

I. INTRODUCTION: WHAT IS SITUATIONAL AWARENESS?

This paper describes how a dynamic process model can represent situational awareness. We'll begin by describing the overall need, defining terms and specifying goals in this introduction. In Section 2, we'll summarize the specific characteristics of a process model that might be used to represent this situational awareness. In Section 3, we'll walk-through how the definition and goals of situational awareness can be thought of in terms of this process model. In Section 4, we'll describe the fractal characteristics of situational awareness and the corresponding process model. We'll conclude in Section 5 with a discussion of next steps, and in particular the opportunity to better visualize and manage situational awareness in Mixed Reality applications. Enabling situational awareness in smart avatars is one of the goals for the coming year. Let's begin with some definitions.

What is "Situational Awareness"? From a lay perspective, definitions of "**situation**" include:

- a set of circumstances in which one finds oneself; a state of affairs of special or critical significance; critical circumstances at a given moment; position or status with regard to conditions. [1]

After reviewing these definitions, including the sub-definitions for words like "circumstances", and considering them as a whole, we can identify certain fundamental characteristics of **situational awareness**, including:

> (1) a *set of facts* or opinions; (2) tied together by *some common aspect*, e.g. location, person, event; (3) *relevant* for some goal or mission; and (4) of *some significance*.

For example, if I am in a car accident, my "situation" might include the condition of the people in the car, the car itself, the degree of injury, the location, and the need for help or services. These are a set of facts or opinions, tied together by the person (me) and the event (the accident), relevant for my ongoing goal of continued health for me and my companions and the continuance of our journey, and significant for getting us up and running again. Irrelevant facts such as what I'm wearing, or the type of damage to the pavement, or the time of

day are not part of the "situation" (although they might be relevant if we view the "situation" from a different perspective as we'll discuss later).

So we've considered a lay definition of a "situation", but what do we mean by "awareness"? **Awareness** is:

- *knowledge or perception of a situation or fact*; *feeling, experiencing or noticing something*; *knowing and understanding a lot about what is happening in the world around you*. [2]

These definitions imply different degrees of awareness. "Knowledge" of something seems to go beyond perception to include a deeper appreciation or understanding, what one might term situational "assessment". **Assessment** is:

- the *evaluation* or estimation of the nature, quality or ability of someone or something; the act of making a *judgment* about something; the result of *judging the worth or value of something*. [3]

So from these considerations, we might extend the characteristics of **situation awareness** to include:

> (5) perception of the key facts; (6) from a relevant perspective; and (7) an understanding of the value of or the impact of those facts on our ability to achieve our goal.

Later, we will consider how a process model can have these same characteristics and so effectively represent situational awareness. But first, let's consider how the lay definition of situational awareness has been refined in the literature relevant for battlespace awareness, so we can refine our characteristics accordingly.

An oft-cited definition of situational awareness from the cognitive science literature on command and control related to aviation reads:

- "..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" [4]; "Situation Awareness can be thought of as an *internalized mental model* of the current state of the operator's environment – the many streams of incoming data, the external surroundings, and other concerns must be brought together into an *integrated whole*. … SA therefore involves *perceiving* critical factors in the environment (Level 1), *understanding* what those factors signify (Level 2), and *anticipating* what will happen with the situation in the near future (Level 3). [5]

These definitions are not too different from the lay definitions, but focus a bit more on the time aspects: past, present and future relevance of situation awareness. These refined definitions also mention a "mental model of the current state" from the operator's perspective, managing the "streams of incoming data", and integrating the many complex parts into a presumably simpler integrated whole. So from these definitions we can add a final few characteristics of **situation awareness**:

> (8) *mental model*; (9) *integrating complex data* into a simpler whole; and (10) an appreciation for the *past* (actions and states of affairs to assist understanding the present situation), *present* (awareness and understanding of the present situation), and *future* (impact on remaining steps to reach the goal).

II. DAPM: A Quick Overview Of The Dynamic Agile Process Model

In a recent paper, the authors described a Dynamic Agile Process Model (DAPM) and its relevance for enabling an agile training framework. [6] We will provide a short summary here of that model and highlight the aspects relevant for our discussion of situational awareness.

A "process" can be represented as a sequence of steps where each "step" represents an action that has an input and an output "product". In the case of the DAPM mentioned, the steps can be linked via the products (specified by URL) or product filters (also specified by URL), providing a level of abstraction that enables process steps to be linked flexibly, dynamically and autonomously. See Figure 1. These process representations ("models") can be derived from many sources, such as Joint doctrine for best practices for Joint Close Air Support, Air Operations, or other activities. The products represent interim or final results and are instances of generic product types relevant for command and control such as Observation, Course of Action, Request, Approval, Decision, and Metric. See Figure 2.

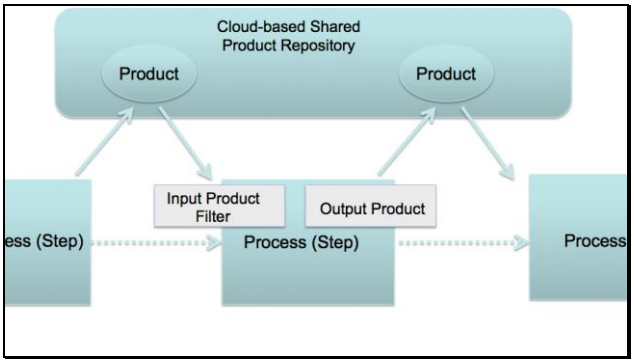

Figure 1. The Process Step Building Block

With the DAPM, a user can define output products for each step in the workflow in a progressive, generic, hierarchical, machine-understandable and addressable format such as JSON-LD [7], including property/values and links to parent/child product types, and linked data. The definitions of the products and processes can then be utilized in a *supporting framework*, such as the RESTful http-based web [8], to enable distributed, decentralized implementations. When a step in the process has the data inputs it needs, the step executes. This data-driven [9] approach, including the linked data, filters, and progressive formats, allows the steps in a process to be triggered by inputs coming from any other process step, if

they pass the filter, thereby enabling new process creation and new process behavior which is *dynamic and autonomous*.

The focus of the DAPM is on the agile and dynamic representation of the processes, not on the execution engine; however, the design of the representation includes assumptions about the agile execution needs [10] for dynamism, scalability, autonomy, and distributed functionality. For example, rather than have a process engine that "drives" the process according to some hardcoded process flow, the DAPM allows steps to proceed in whatever order as long as they have the needed inputs. This enables process steps to be skipped or for new processes to be inserted to drive existing processes, for parts of processes to be seamlessly reused by other processes, and for new processes to form automatically if the inputs and outputs for subprocesses match.

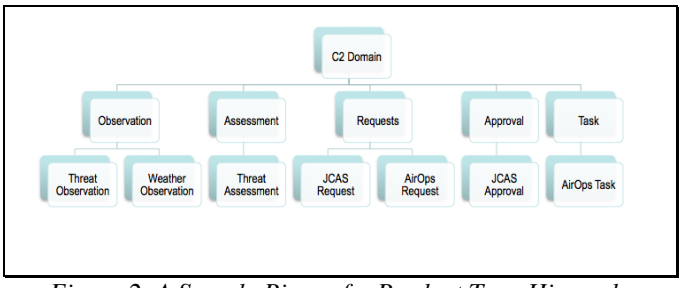

Figure 2. A Sample Piece of a Product Type Hierarchy

This means that process steps can be skipped and inserted, that processes can *self-integrate*, and much *greater reuse of processes and subprocesses* is possible without hard-wiring, recoding and without requiring costly, brittle, and unscalable orchestrated centralized control.

III. THE TIE BETWEEN DAPM AND SITUATIONAL AWARENESS

Let's consider this Dynamic Agile Process Model (DAPM) and see if it has the ten characteristics we derived from the definition of situational awareness in Section I above. Let's consider our list of characteristics of situation awareness one by one and see if there is a corresponding characteristic in our process model:

(1) A "situation" is a set of facts…

Our process model consists of a sequence of actions each of which is intended to produce a product and the collection of those products are a representation of the "facts". For example, if a step in the process involves a transport of a unit to a given location, then the output "product" is the location of the unit, represented by a unit position report. If the goal of that step was met, then the position of the unit is at the goal location; however, whether the goal is met or not, the unit location is a fact. Other facts are represented by other products of our process or by other processes.

(2) …connected by some common aspect, e.g. person or location; …

A set of processes may have a common aspect, such as having the same operator or involving the same location. These processes, in the DAPM, can be found by searching the process repository for processes containing this common aspect, which is the basis for the intersection of the processes. For example, "my" situation is the intersection of all ongoing processes where I am the operator. The car accident "situation" is the intersection of all the processes involving my car, the other car, the occupants, the responders and the geographic area. We'll see that we can focus this "situation" by looking at it from a given perspective. For example, if we consider the car accident from "my" perspective, then we are looking at my health and status. This perspective provides focus and filters the vast amount of information. .

(3) ….related to some goal or mission;

There are many facts associated with a person or place, but for those facts to be of relevance for situation awareness, they must be related to a goal or mission. Process models are used to capture business processes for achieving specific goals and missions. So the use of process models for representing situational awareness is a natural fit in this regard. Built into the representation is the notion that the output products from each step in the process relate directly to a goal or mission.

(4) …of some significance, i.e. significantly impacts our ability to achieve the goal.

Since processes are intended to accomplish a goal, often including metrics to determine if the goal is reached, and a process model is a distillation of the most significant steps of the process, then the process model naturally contains products which are significant. So the use of processes to represent situational awareness offers direct linked connection between significant facts (products) and the process goal.

(5) Situation "Awareness" is the perception of these facts by an agent (a person or system); …

Awareness in the form of perception can be direct or indirect. For example, I can directly observe a car accident if I happen to be at that location at that time but most of the time I would gain my awareness by being told about it. Just as with people, machine systems can "perceive" directly or indirectly. A video camera mounted on one of the vehicles or pressure sensors in the bumper may enable the machine to directly "perceive" the accident and the car may send a message to an emergency response computer which gains its form of awareness indirectly. If we have a machine representation of situation awareness which can be updated by a computer or human and shared with other computers or humans, then we have both direct and indirect perception covered.

(6) …from a relevant perspective;…

The perspective could be a particular person's perspective, or a particular role, or a particular location, basically anything that allows an appropriate filtering of the

massive amounts of data. The DAPM supports filtering on these elements.

(7) … with an understanding of the impact of those facts on future actions taken to achieve the goal…

Simple awareness of facts as noted is often not enough; some assessment of the facts is needed to understand their impact on the goal. Since understanding the impact of current facts on future goals is never perfect, it might be better to think of this as the ability try to represent probabilities or weights on the most likely outcomes given the current situation. With the DAPM, weights could be applied to the desired outcomes at each step, and process flow or lack of flow could be considered or predicted, and in this way, one can envision that a machine could begin to "consider" the impact of current facts on future actions and whether that impact is positive or negative relative to the goals of those processes. Although this may not be true "understanding" of situation awareness, it is a useful start.

(8) …represented as a mental model;…

A process can be one representation of the mental model of a person performing that process. The DAPM is a process model which can be understood by a person or stored, accessed, searched, and managed by a computer system. If we hope to utilize computers effectively to assist us with our major tasks, rather than just use them as telecommunication devices, then it's important to have not just a mental model but also a corresponding machine-understandable model.

(9) …useful for integrating diverse complex data streams into a simpler whole;….

As we'll see later in the discussion of fractals, the DAPM's organization of processes and products in a generic, hierarchical, iterative fashion lends itself to enabling the representation of complex systems from simpler component parts. The earlier discussion of the DAPM support for filters and perspectives also addresses in part this need to manage complex data.

(10) …incorporating past (actions and goals), present (state of affairs) and (impact on) future (actions).

If we are in the middle of a process, then the previous steps in the process represent the past and help to explain how we got here in terms of actions and goals. The current states of all the intersecting processes and their products represent the current state of affairs. And the future steps in the processes can be used to judge the impact of the current facts on the future.

IV. THE FRACTAL NATURE OF SITUATIONAL AWARENESS

One solution to generating and managing complexity in nature is to have a fractal design. [11] A fractal is self-similar, which means that when you zoom in on a portion of the whole system, the portion resembles the whole system in structure. For example, a branch of a tree appears structurally similar to the whole tree. What are the advantages of a branching fractal design? Branching designs show up in biological systems, such as trees, roots, lungs, and arteries; however, they also appear in other areas of nature such as networks of rivers and streams. The problem solved by this branching is how to enable and balance the distribution or collection of resources (oxygen, nutrients, water) across a large surface area with the speed and volume of material distributed. So for example, how does one distribute oxygen to every living cell in the body after breathing in one large breath of air. The lungs use a branching solution to create in the human chest an absorbing surface area that is as large as a tennis court. This solution for managing surface area and volume can help us address management challenges, such as situation awareness.

Situation Awareness similarly involves filtering and aggregating each piece of knowledge (small volume) across the whole span of our mission (wide surface area) into an overall large piece of knowledge, i.e. an assessment (high volume) of what we should do next (low surface area). [12] Humans naturally aggregate and branch information into a cognitively manageable set of a relatively few items (e.g. 7) at various levels. [13] This branching resembles the fractal branching and offers the same advantages and enables the same simple pattern and self-similarity at each level. If this is true, then a good model of Situational Awareness would exhibit the same type of branching, summarization and aggregation.

The DAPM has a fractal branching design. The DAPM enables branching through its use of URL links to child processes or parent processes. So each process step can be linked to a small number of substeps. This "progressive" organization of process steps, where the detail is progressively revealed as one traverses the process tree, enables DAPM to model the desired fractal branching design of situational awareness. Each step in a process, no matter the level, shows the same linking structure, thereby providing self-similarity.

The DAPM enables aggregation by having its own data values at each level for assessment, including percent complete and mission impact. Each process step can have an assessment or decision as its input or output product and thereby distribute these assessments or decisions across the architecture. The products, in addition to the process steps, are organized by their types into a hierarchical generic structure, enabling aggregation and summarization. This infinite self-similarity can be modeled to any desired level with the DAPM.

In short, the DAPM design is fractal in nature, which matches this characteristic of situation awareness, and offers the advantages of improved human understandability and a representation supporting a manageable collection of information for assessment and manageable distribution of orders for execution.

V. NEXT STEPS

In 2016, SSC Pacific will be exploring the DAPM for situational awareness for undersea warfare and related domains in the BEMR lab. The Battlespace Exploitation of Mixed Reality (BEMR) lab began in 2015 with a grant from ONR of BlueShark equipment and software developed by the University of Southern California's Institute for Creative Technologies (ICT). The lab includes a six-foot avatar, a synthetic environment of a ship deck, a 3D interactive display for repair of a robotic arm, and a series of immersive environments. Including the latest technologies from leading companies such as Oculus, DAQRI, ZSpace, Samsung, Microsoft, and others, the lab serves as an excellent environment for exploration, education, development, and demonstration of mixed reality solutions.

In association with BEMR, the Advanced Exploitation of Mixed Reality (AEMR) Community of Interest (COI) provides a forum for organizations and entities to come together, identify needs and use cases, explore new Mixed Reality technologies, demonstrate interoperability solutions, and address issues of community interest. One of the challenges facing the AEMR COI is the ability to represent, manage and share situational awareness across Mixed Reality applications, including applications attempting to utilize smart avatars. This is one of the issues being discussed in the Smart Avatar working group. Solutions, such as the one proposed in this article, offer the potential to address this issue, enabling avatars to function with a machine-understandable representation of situational awareness. You are welcome to join the AEMR community. Your participation is vital to our combined success. To join or participate, please send an email to bemr@spawar.navy.mil.

VI. CONCLUSION

The authors in this paper considered the definition of situational awareness, extracted defining characteristics from these definitions, and then suggested that a Dynamic Agile Process Model (DAPM) captures those some characteristics, such that a machine-understandable representation of situational awareness can be considered the intersection of processes. The Dynamic Agile Process Model (DAPM) has certain characteristics, including both static and dynamic aspects, as well as fractal characteristics which seem to match the similar characteristics of situational awareness. The ability to represent, monitor and drive these processes, enables shared situational awareness between people and systems that will then have an improved ability to assist with effective and efficient command, control and decision-making.

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