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Title: Intelligent Nodes in Knowledge Centric Warfare

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Abstract

With the continuous increase in complexity and tempo on the modern battlefield, new demands are placed on information dissemination. The volume of information available to the user becomes larger while the time necessary to correctly interpret and understand this information becomes prohibitively smaller. Cognitive processing of information at the user nodes is proposed as a potential solution to this information overflow problem. These nodes we will call Intelligent Nodes [Dawidowicz, 2001]. This paper will introduce the architecture of an Intelligent Node and will demonstrate its hierarchical scalability across all echelons and Battlefield Functional Areas. This technology is directly applicable to the Objective Force and Future Combat Systems.

Keywords: *Objective Force, Future Combat Systems (FCS), Command, Control, Communications, Computers, Intelligence Surveillance and Reconnaissance, (CAISR), Network Centric, Knowledge Centric, actuation, behavior generation, commander's intent, conceptual graph, functioning, knowledge representation, battlefield, behavior generation, entity-relational network, heterarchy of organization, knowledge, knowledge management, messages, plan execution, and semantic network*

1.0 Introduction

The concept of Network Centric Warfare is a natural continuance dictated by technological advances in the areas of computing and network communications coupled with an always-present decision-makers desire for having the right information at the right time. It is also recognized that the amount of information available could become a burden for the decision-maker, as the time required¹ in making a decision is diverted for the tedium of information processing.

To resolve this problem intelligent assistants or agents are essential to help decision-makers with information processing. A Methodology for designing 'intelligence' apparently remains elusive. There are several reasons responsible for resolving this difficult problem. The first one lies in our limited understanding of exactly how the human brain works. The second is that we are all too eager to apply well-known methods, for example, classical design of expert systems that we fail to see other

potential solutions. We can probably cite a few more reasons but that would take away from the main purpose of this paper, which is a description of a potential surrogate solution to real human intelligence.

We recognize that computers as we know them today, due to their intrinsic architecture, are limited and can only function as menial computational tools. However, machines possess an unrelenting and untiring ability to process numbers. If we can find a way to map abstract concepts into numbers then perhaps computers could rise a step or two on the intellectual scale and provide us with the sought after capability of becoming these somewhat intelligent assistants.

The strength of the proposed design is manifested by two important concepts. The first concept lies in grounding the decision-making process to the quantitative data extracted from the message traffic coupled with a physical model of the battlespace at a lower level. The second concept lies in a goal-oriented search for a solution where the commander's intent, mission, task or threats determines the goal. The uniqueness of this approach stems out of a previously tested and original architecture¹, which allows fast computation in otherwise combinatorially burdened spaces. Fast computation is achieved in part by modeling the computational spaces into several levels of resolution [J. Albus, A. Lacaze, A. Meystel, 1995] coupled with unique but proven algorithms. The proposed architecture can serve the Network Centric and Knowledge Centric paradigms as well as become a general architecture for intelligent agents or for a system of intelligent agents.

2.0 Few Important Concepts

2.1 Modeling of the World and Context

Computers cannot understand the question "How fast is that object moving?" A human or a computer could respond with "20 km per hour", but a human can also provide a better answer, depending on the context within which the question was asked: "Very fast", "Fast", "Slow" or "Very slow". If we think that we can accomplish that with a "***If Sensor (argument list) Then Effector (argument list)***" statement, then we are missing the point, since computers do not have the faculties to understand the context in which the question is asked. To make the computer answer a question in the proper context, the computer must be aware of the environment in question. We can address the aspect of awareness within the computer by modeling the environment in an entity relational network [Dawidowicz E, 2000], where the objects, which constitute the environment, relate amongst each other. The methodology for modeling this environment is beyond the scope of this paper, however it would suffice to say that the information required resides in doctrine manuals, textbooks of classical physics and data describing the areas of interest.

2.2 Decision Making or Behavior Generation

Once the world or environment is modeled, the basis for decision-making or behavior generation is found. Changes in the world model are detected as the world model at t-1 is

¹ The architecture proposed here is employed in the Automated Ground Vehicles (AGV) currently under development for Future Combat Systems program

compared to the world at time t . These changes stimulate an entity relational network, which in turn produce measurable changes in the relationship of existing objects. Before the decision-making process can begin to produce 'decisions', one very important ingredient is required. This ingredient is called the goal. A goal (or set of goals) together with the ability to detect changes within the world model allow for the decision-making process to take place.

2.3 Sensors and Sensor Processing

But how does our computational framework realize that the world has changed? It needs sensors. The information provided by sensors stimulates the internal world model. At this point it is important to call the world model a knowledge representation repository. It seems natural to call the world model a knowledge representation repository since our knowledge about the world around us is being represented as the model of "our" world. Certain distinct sensory stimulation could mean little unless we have experienced them before, but before any meaning can be attached to these stimuli, they have to be converted to information, which our own knowledge representation can understand. The signals produced by the outside world have to be detected by the sensors, and then in turn must be processed intrinsically to our knowledge representation. Sensor processing performs the informational mapping between the sensors and our knowledge representation.

2.4 Contemplation or Imagination Loop

A Contemplation or Imagination Loop is a process within the Intelligent Node framework that facilitates intelligent behavior. Sensor processing supplies information to the knowledge representation repository, and the detection of any change in state triggers

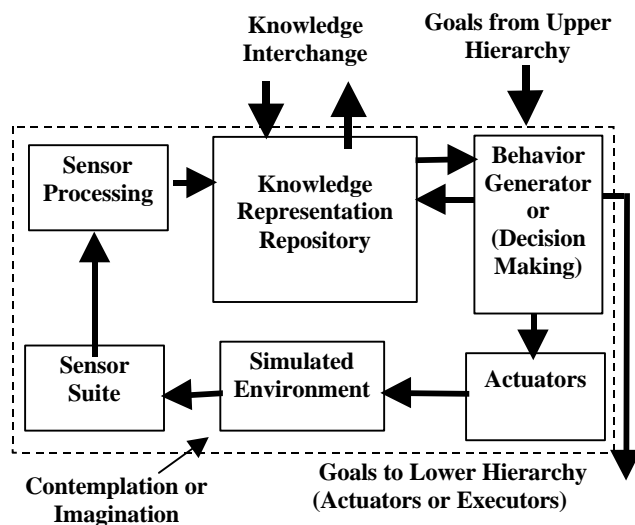


Figure 1. The Elementary Loop of Functioning (ELF)

behavior generation. The behavior generator, in attempt to check whether new information may suggest a deviation from the plan or a potential threat, initiates a simulation loop. Sounds almost like "... the dog bit the cat, the cat chased the mouse, the mouse cut the rope, the rope tripped the farmer...", but where is the intelligent behavior? The intelligent behavior emerges when the behavior generator implicitly raises several questions and attempts to simulate a number of solutions. This thinking loop is the Elementary Loop of Functioning (ELF) shown in Figure 1. A goal (or sets of goals) together with the

ability to detect changes within the world model allow for the actual decision making. The ELF becomes a critical building block in the Intelligent Node infrastructure.

2.5 Goals

The mission, mission thread, concept of operation or unit tasks can be decomposed into sets of goals. Through the development of a course of action statement and sketch, the mission statement “Co A will arrive at Assembly Area Tiger at 060140Z Aug 2002”, can be decomposed into a set of goals:

- **Goal 1:** Perform route reconnaissance and planning (By what route will Co A travel to get to AA Tiger)
- **Goal 2:** Determine the potential threats and risks. (Where could they expect to be ambushed or attacked)
- **Goal 3:** Determine the march order and formation based on goals 1 and 2. (What is the march order and formation of Co A.)
- **Goal 4:** Determine the resources required to execute the task. (Do they have the required resources to accomplish the mission? If not, can the missing resources be acquired? If the resources are not available, \ what are the alternatives? Use the alternatives to redefine or refine the applicable results derived from the contemplation loop or modify the earlier defined goals.)

3.0 Military Planning Process

The Intelligent Node architecture has many applications outside the military domain, but since our work is focused on the warfighter, we therefore limit our efforts to the

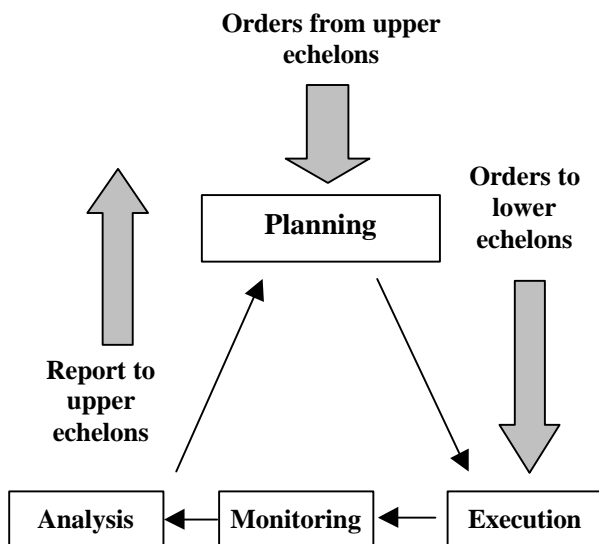


Figure 2. Military planning process

continuous military planning process. Military planning is a continuous process and our proposed architecture compliments this process well. The architecture of ELF is designed for continuous planning triggered by incoming information. A command, mission or orders received from a higher echelon with a clearly stated commander's intent, initiates the military decision making process (MDMP), which is a planning-execution process (Figure 2). This process can be generalized as a sequence of steps: A higher Operational order initiates a goal-oriented collection of information via communications, generation of decisions, and contemplation of their execution. Planning is defined as programming of the system's functioning based on the received order and the available information. As a result of planning, several courses of action (COA) are developed leading to several alternative plans. A final plan is defined as a collection of schedules

for independent and/or properly distributed and synchronized processes of functioning subsystems that keep the cost functions within set boundaries. These processes are defined and distributed as sets of orders and verbal instructions to the lower echelons of the organization.

1. Execution starts as soon as the plan is put into action.
2. The execution is continuously monitored.
3. The plan execution is monitored via the continuous interpretation of information contained in messages received from higher and lower echelons.
4. If analysis of this information suggests that a deviation from the original plan is taking place, and this deviation may inflict undesirable consequences, the commander and the unit-planning cell will plan for continued action.

The commander and the members of the unit planning cells are part of our Intelligent Nodes. They aid in the processes of the Decision Making or Behavior Generation element of the ELF.

4.0 Intelligent Nodes

The ELF architecture is well suited for developing the architecture of the Intelligent Nodes, however this requires explanation and will become evident when we discuss how the ELF fits into the Intelligent Node framework. A planning cell is an instance of the Intelligent Node, where warfighters and automation_work together towards a common goal. The scope of this paper is limited to a discussion of the automation part of the Intelligent Node.

4.1 Levels of Resolution and Collaboration

For the purposes of our discussion, the KRR within the Intelligent Node will be limited to only three² levels of resolution:

- The level above to understand the commanders intent
- Own level (echelon level of a particular node) to generate individual goals and perform planning and monitor execution.
- The level below to understand how subordinate units responds to the higher commander's intent.

This type of modeling allows us to simplify computation dramatically, allow for inter-echelon understanding and support a critical element called collaboration. Also, this modeling is doctrinally valid since the lower the echelon, the higher the granularity required for planning and execution. For example, we will need more detailed information driving a car than planning the overall trip by car. When we plan a trip between two points we want to know where the bridges are, which roads have light traffic and reasonable speed limits. This is an example of coarse resolution. An example of fine resolution would be the type of road, the mix of traffic and the number of road signs per mile. Using different levels of resolution helps us to simplify computation by orders of magnitude. For example, if we plan a 10-km route and become concerned about a 50-centimeter pothole along our path, we would need a digital terrain database with a resolution of less than 25 centimeters (this is about 40,000 terrain elevation points in

² According to the doctrine, modeling of four levels of resolution is required.

10km). By dividing the total distance into segments and a segment into smaller and smaller segments we are introducing correspondingly different levels of granularity per segment. We can then state that at every level of granularity we will deal with about the same number of points, let us say arbitrarily 100. Based on our example, first we are concerned with the overall distance, whether we want to stop somewhere, and the approximate total time that it will take us to get there (100 points). The second level of granularity would be a further refinement, such as what road to take, when to turn off, which places we want to stop while en-route (another 100 segment of higher resolution, but only at the points of interest suggested by the coarser resolution) and so on.

The example used here in terms of terrain elevation points can be extended to other objects and using their own particular attributes to form relationships, we can structure entity-relational networks, where the aspect of granularity becomes extremely important.

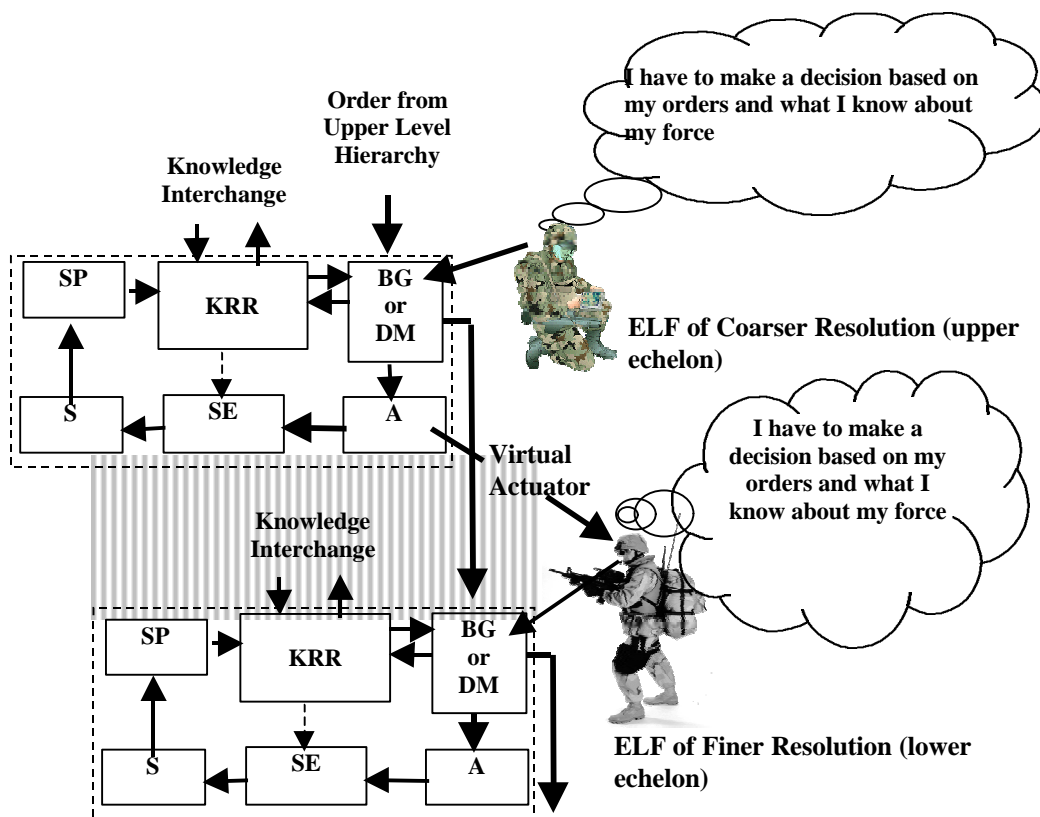


Figure 3. Commander and Subordinate Commander Intelligent Nodes

The entity relational networks by themselves can thus become indispensable computational tools.

Collaboration among Intelligent Nodes is yet another powerful concept. As we reduce the computational complexity by using multi-resolutional modeling, we can reduce it even further by using distribution of labor among our Intelligent Nodes for the planning process. For example, since all three companies are at the same level of resolution and intend to take the same route, it appears that only one company needs to do the route

planning while the other company may consider detecting areas of potential ambush while the third company is able to look for available assets. In the process of continuous collaboration the KRR of every Intelligent Node gets updated therefore maintaining information/knowledge sharing and continuously updating the Common Relevant Operating Picture (CROP).

4.2 Putting the Concepts Together

The ELF architecture allows reasoning in terms of physical object representations, their relationships to each other and continuously computing the cost functions associated with changes within the area of interest and updating the World Model. Multi-modal data, or data from different sources, is processed for task or situational relevance. ELF is incorporated into Intelligent Nodes as the main building block allowing the Intelligent Nodes to maintain a continuous awareness of the relevant environment and continuously analyzing pertinent or emerging courses of action. This allows the contents of messages; sensor data or user requests to be mapped into the world model to quickly and intelligently respond to deviations in planned execution, emergencies or threats. Intelligent Nodes are capable of the following:

- Intelligent assistants
- Robotics
- Collaborative agents
- Tool for Mission Planning, Course of Action Analysis, Situational analysis, Natural Language Interface
- Process control and optimization agents
- Biometric information collection for security profile, and intrusion detection.

5.0 Conclusion

The current Future Combat Systems (FCS) program, together with the ongoing rapid evolution of the Army into a futuristic, multifunctional Objective Force, requires implementation of new ideas and concepts into current and developing combat systems in which machines will synergistically work together with humans to achieve quick and decisive victories with minimum loss of life. The concept of Intelligent Nodes presented in this paper will provide that critical capability and environment, where machines will be able not only to communicate with humans in a natural language [S. A. Carey, et al 2001], but will also understand the interaction of other users and the message traffic within their environment and in the proper context, thereby reducing manpower and produce the on demand or requested right information at the right time.

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