Improvement of Shared Awareness in Sensor Grid in Three Levels of CommonKADS Framework

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Abstract.- Given the need for real-time information and data as well as distributed computing, large-scale sensor grid is a great option to make more precise decisions in management and control of large-scale organizations and environments. For this purpose, it makes sense for integration of the two technologies of sensor networks and grid computing which was done here based on Observation, Orientation, Decision, Action (OODA) intelligent architecture and Elementary Loop of Function (ELF) decision making models. To this end, the simulations were conducted based on CoomonKADS framework at three levels including simplicity, composition and analysis. The results of the simulation indicate that as the number of network elements (resources and users) increases, namely, the large scale performance, the level of shared awareness significantly increases. As the acquired data and knowledge are either stored or retrieved from other sources and given the large-scale resources' life reduction, the findings also show that shared awareness will not be significantly decreased with reduced resource life at a very large scale. The great note about the results is that the best mode of shared awareness is obtained when we have the highest scale of users and resources.

Keywords: sensor networks; grid computing; OODA; ELF; CommonKADS.

Mejora del conocimiento compartido en malla de sensores en tres niveles del framework CommonKADS

Resumen.- Dada la necesidad actual, en la gestión y el control de grandes organizaciones, de información y datos en tiempo real, así como también de computación distribuida, una red de sensores a gran escala es una gran opción para la toma de decisiones precisas. Para ello, tiene sentido para la integración de las dos tecnologías de redes de sensores y computación en red que se hizo aquí sobre la base de la observación, orientación, decisión, acción (OODA) arquitectura inteligente y bucle elemental de la función (ELF) modelos de toma de decisiones. Con este fin, las simulaciones se llevaron a cabo sobre la base del marco CoomonKADS en tres niveles, incluyendo simplicidad, composición y análisis. Los resultados de la simulación indican que a medida que aumenta el número de elementos de red (recursos y usuarios), a saber, el rendimiento a gran escala, el nivel de conciencia compartida aumenta significativamente. Dado que los datos y los conocimientos adquiridos se almacenan o recuperan de otras fuentes y se les da la reducción de la vida útil de los recursos a gran escala, los resultados también muestran que la conciencia compartida no se reducirá significativamente con una vida útil de los recursos reducida a gran escala. La gran nota sobre los resultados es que el mejor modo de conciencia compartida se obtiene cuando tenemos la mayor escala de usuarios y recursos.

Palabras clave: sensor networks; grid computing; OODA; ELF; CommonKADS.

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1. Introduction

In today's age, the need for real-time information and data as well as distributed computing is deeply felt to make more precise decisions in management and control of large-scale organizations and environments. The large-scale sensor grid creates this capability [1]. Such a sensor grid network is composed of several wireless sensor nodes. Generally, the mentioned sensor nodes own restricted resources and computing power. As a result, the computational tasks which are resource demanding and/or computationally intensive need to be partially or mostly offloaded to a place other

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than the sensor devices for prompt processing. In addition, the data collected or created by these sensor devices have to be transferred over the sensor grid network [2]. Besides, the four characteristics including distribution, decentralization, diversification and change are key features of large-scale organizations. In the framework of large-scale sensor grid, the purpose of such an infrastructure is to give freedom to any user in any functional area to create a true sense of the environment and thus to utilize the experience and results to control the environment more effectively. Challenges in this area often include the development of conceptual models for two-way information exchange, software platforms that support these new communication processes in a technology-independent way, and ways to ensure security, trust and efficiency in data exchange [3]. The Large Scale Sensor Grid is a dynamic repository for generating and storing information to produce intelligent outputs for various organizations. The Large-Scale Sensor Grid is a system that is accessible to various organizations and institutions and can be developed to meet the needs of organizations. The overall goal is to build a system that is useful for different applications and organizations with different processes, expandable over time, and can be used as a platform for receiving information and knowledge in an updated and integrated way. The large-scale sensor grid is designed to allow easy collaboration between sensors' data sources from different applications, storage and processing repositories [4]. Any application by the user proxy interface can adapt the system to meet its specific needs and manage the processes. In fact, proxies in three parts can handle the complex problem of how to modify the different workflows needed for multipurpose systems. In addition, a number of services and requirements for interoperability and exchange of information, facilities for communication and interactions between information sources and capabilities, are needed as infrastructure to meet the sensor grade communication and information needs by the sensor grid (Figure 1). In other words, the Grid has knowledge of services about how information is sent, by whom, and with what restrictions [5].

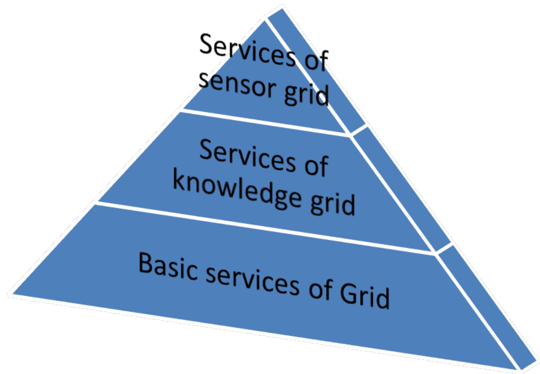

Figure 1: The relationship between services of sensor grid with other services

To this end, some similar studies have been conducted for integration of sensor networks and grid computing. For instance, the Sensor Grid Project of Singapore International University aims to utilize the computing power, storage, and grid connectivity bandwidth to support sensors with limited resources. They practitioners in this project try to have data mining and decision making in real time, and recently they have claimed that their architecture based on web-based connections between sensor networks and grid computing (based on the Globus Toolkit4) is capable of delivering distributed data mining. Similarly, the Sensor Grid project at the University of India also seeks to create a grid of grids based on the integration of web service technology into a Service Oriented Architecture (SOA), while their middleware is based on such brokers as Narada Brokering (Sensor Grid in University of Indiana, http://www.crisisgrid.org/html/introduction.html) [6].

In present study, using CommonKADS framework, sensor networks and grid computing were integrated based on Observation Orientation Decision Action (OODA) smart decision making models and Elementary Loop of Function (ELF) smart structure architectures. In a smart system, computational loops are constantly repeated from sensor to action, from global model to sensor processing, and from behavior generation to global model to quantitative evaluation. These loops are repeated long enough to meet the target threshold based on the variety of sensor and action capability [7]. One of the benefits of interacting with sensor elements is improving shared awareness and thus providing a better mental model for different organizations. Being aware of what is happening in the surroundings is a matter of Shared Situation Awareness. Team members must gather and aggregate all input data from different systems, external environments, peers and others in order to gain Shared Situation Awareness. This holistic image organizes a central feature that fits into all decisions and actions [8]. Therefore, Shared Situation Awareness is referred to as the overlaps of team member's situational awareness requirements, as shown in Figure 2.

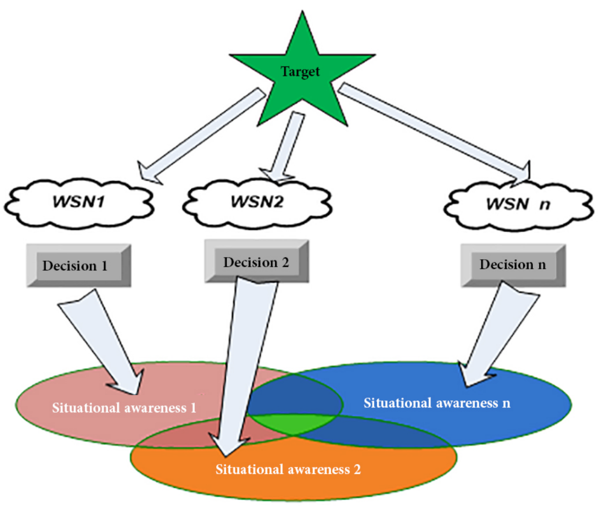

Figure 2: Shared Situation Awareness

As a result, to obtain shared situation awareness, the mental model is effective in attaining reality and situational awareness brings the mental models closer to reality. The shared awareness gained from the interaction between the sensor grid elements has a significant impact on efficient decision making in different organizations [9]. Accordingly OODA and ELF are discussed briefly as follows:

2. Observation Orientation Decision Action (OODA)

The Boyd's Control Cycle or OODA was introduced in 1987 and is actually a cyclic model with four stages including observation, orientation, decision, and action. This cycle was originally developed for military command and for aerial warfare, which was used as a closed loop for understanding human-machine interaction in command and control systems. In other words, this model was introduced to represent decision-support mechanisms for the military systems of that time, and since decision-support systems were using information merging, it was also widely used in data integration. This model is process-oriented and information-based and outlines the overall tasks of a data gathering system. At the observation stage, the sensor data is collected. In the orientation of the data, they are combined to understand the situation. In the decision phase, a plan is provided for responding and finally, the provided plan is implemented in the action phase [10]. Figure 3 depicts this control cycle where arrows indicate the amount of data flow in the loop. Extent to which the data in the loop is refined and transformed into information, the amount of data transferred to the next phase decreases. The advantage of this model is that it is closed loop and acts on its environment and sensors [11].

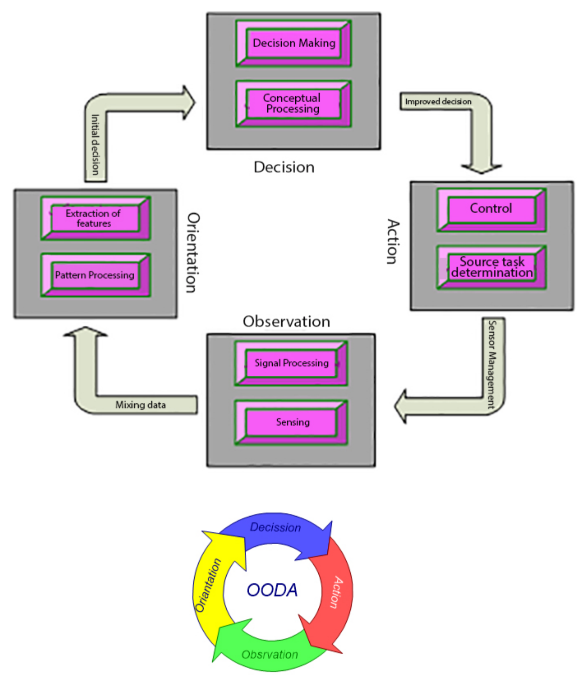

Figure 3: Boyd's Circle (OODA)

In the OODA model, shared awareness is

equivalent to observation and orientation, and we will exit the loop if no shared awareness exists. Therefore, with the proper Shared Situation Awareness, decision making will become faster and entities and teams perform more efficient operations in the environment.

3. Elementary Loop of Functioning (ELF)

An architectural reference model is required to design and engineer smart/intelligent systems. In other words, with the reference model, it is possible to develop engineering models for the design and construction of intelligent systems. Using the Elementary Loop of Functioning (ELF) reference architecture, some guidelines are provided for designing and constructing a Shared Situation Awareness that can perform the tasks similar to natural intelligent systems. The ELF model's approach to the phenomenon of intelligence is a computationally, namely, a system is intelligent if it has these four basic processes: sensory processing, global modeling, evaluating and producing behavior. This model, which is a computational loop with hierarchical resolution, appears in various phenomena such as behavior, perception, cognition, emotion, problem solving, and learning. This model can be used to help formalizing and designing intelligent systems, and providing a framework for implementation of engineering systems [12]. The ELF model's processes specify how to process sensor's data, build, maintain and use knowledge bases, select targets, respond to sensor inputs, and control actions. The sensor processing trend has functions which are in charge of attention, identifying and grouping features, calculating traits, comparing observations to expectations, identifying objects and events, and analyzing status [13]. Figure 4 illustrates the process ELF model.

The process of global modeling constructs and maintains events, entities, relationships and situations. This process also provides forecasts, expectations, beliefs and estimates of possible future actions. Therefore, by storing perceptions and behaviors planned in the global model, learning is shaped here. The process of evaluating the cost, benefits, risks, and expectations of the plan in question is implemented and attributed to the objects, events, and situations achieved in this model. In other words, the process determines the importance, reward or punishment, and the degree of certainty of what is provided in the global model. Finally, the production process selects the behavior of the targets and breaks down the tasks into smaller sections. It also generates plans to achieve the target, coordinating the activities required and ultimately controlling the actions. The link between the processes described is such that a control loop is provided with computational feedback[13].

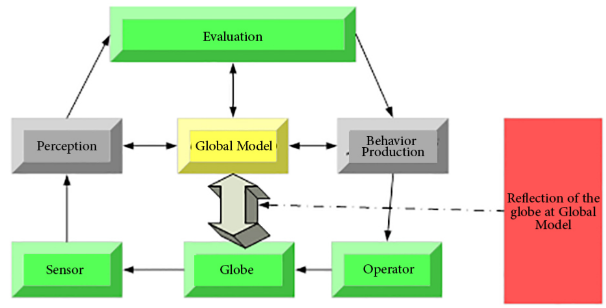

Figure 4: Elementary Loop of Functioning (ELF)

4. Integration Based on OODA and ELF

As mentioned above, the right mental model is one of the key needs in achieving Shared Situation Awareness and ultimately making the right decisions. The mental model is a set of dynamic knowledge structures that have been well-organized and well-established over time. The large amount of data contained in the sensor should not diminish user's decision-making ability. In presenting the large scale sensor grid framework, the basis of the overall performance of the layers is based on the OODA intelligent decision-making model. The performance of the core layer or functional core of the sensor grid, which actually provides the correct mental model, is based on the ELF intelligent system architecture [14].

The overall functioning of the OODA-based large-scale sensor grid is shown in Figure 5. The observation phase is performed by the services provided in the proxy layer of sensor network.

Then, in the grid proxy, with the orientation made based on current data and prior knowledge, the most appropriate decision is made and sent to the user as a result. The resulting shared awareness is equivalent to the observation and orientation phases, and we will get out of the loop in the event of having no awareness. Therefore, with the appropriate Shared Situation Awareness, decision making will be done faster and entities and teams perform more efficient operations in the environment.

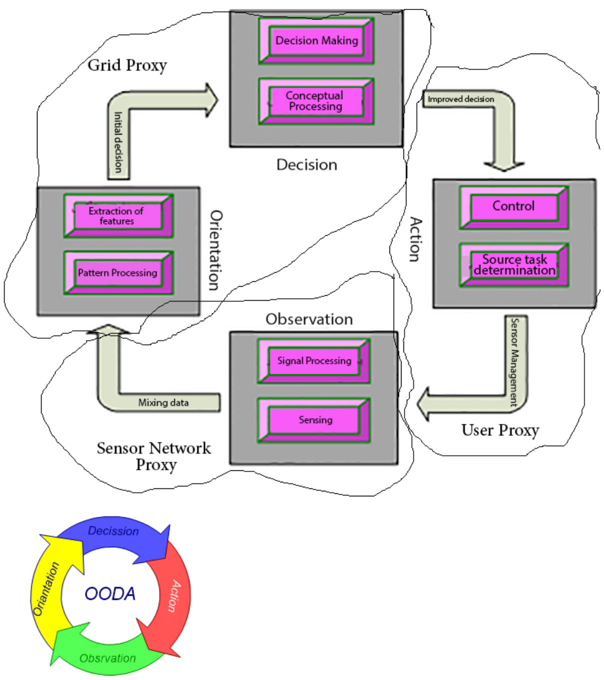

Figure 5: Overall functioning of the OODA-based large-scale sensor grid

In the intelligent system, computational loops from sensor to action, from global model to sensor processing, and from behavior generation to global model to quantitative evaluation, are constantly repeated. These loops are repeated long enough to meet the target threshold based on the variety of sensor and action capability. In other words, repeating ends when the information units in all subsystems reach a consensus on entities, events, and situations, and also the final targets are broken down into specific targets in order to create the command. Figure 6 shows the functioning of the Grid layer and how to achieve shared awareness based on the global model. In the inner circle, the sensed results are compared according to the final targets and the plans will be regularized. Then control is then applied to the globe to provide plans-related results. In fact, intelligence in this model is provided by the interaction between top-down targets and bottom-up sensor feedback. There is also an internal link between sensor processing and the globe modeling, which provides predictions for comparison with sensor observations. In this loop, filtering is performed depending on recursive form of estimation. There is also a link between the processes of generating behavior, evaluating and modeling the globe that simulates and assesses the preliminary plans in the internal planning loop before selecting and executing the design.

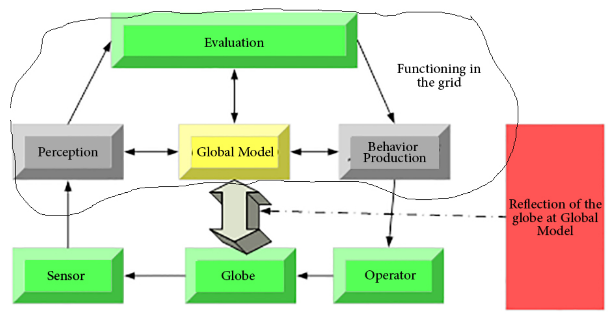

Figure 6: Functioning of grid layer based on ELF reference model

Computational loops hierarchically and repeatedly lead to deeper phenomena such as behavior, perception, cognition, emotion, problem solving, and learning. All the subsystems providing entities, events, and situations, as well as subsystems that break down the targets into sub-targets and prepare action commands, exchange the provided information units at each level and between levels. In each loop, the process of globe modeling maintains the knowledge with specification of a knowledge domain and the degree of knowledge dissociation.

5. Simulation

The CommonKADS (Knowledge Acquisition Design System) model was used to simulate the performance of shared awareness derived from the large-scale sensor grid system. This model is one of the models proposed to analyze the knowledge required of such environments. Inspired by this model, a three-tower approach with three levels of analysis, composition, and simplicity is used to design shared awareness in sensor grids. This model answers three basic questions of why, what and how. The analysis level answers why questions such as existing system capabilities to solve problems, usefulness and impact on the organization based on existing cognitive theories. In fact, understanding the environment at the analysis level answers the question of why. In order to respond the question what, the composition level answers the used knowledge structure and the needed communications. Finally, for answering the how question, the simplicity level determines the implementation of computational mechanisms by presenting a methodology [15]. Figure 7 presents the conceptual framework of CoomonKADS and simulation approach of shared awareness of sensor grid.

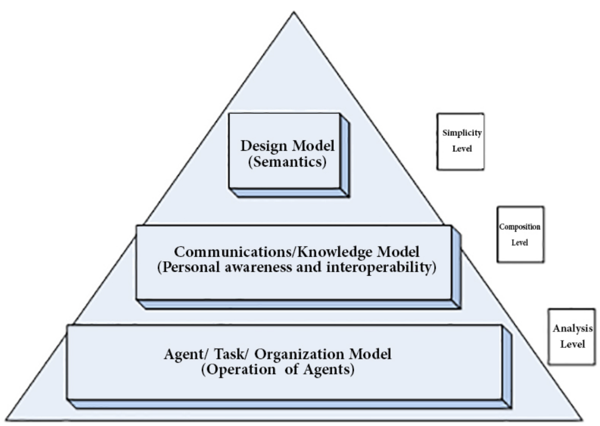

Figure 7: Conceptual framework of CoomonKADS and simulation approach of shared awareness of sensor grid

In fact, some set of threshold values should normally be defined as the necessary condition for collaboration among members to achieve shared awareness in network-centric organizations as determined by the system architect. In other words, achieving shared awareness has been formed based on individual awareness in different organizations as the result of planning and interaction and collaboration between knowledge-based agents in the environment, leading to shared awareness and improved decision making. Figure 8 depicts the way of behavior production in sensor grid based on shared awareness.

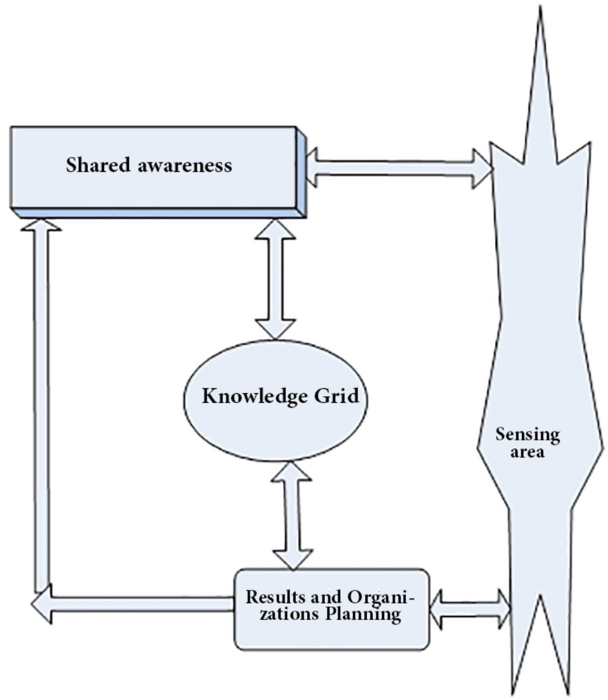

Figure 8: The way of behavior production in sensor grid based on shared awareness

For the simulation, the software Netlogo was used to simulate complex time-varying systems. In this platform, many independent agents can be implemented. In this platform and model, information exchange between resources in the environment was simulated to measure the level of awareness (Figure 9).

According to exchange between people and resources, the increased level of awareness created at a certain threshold was considered as a source of new knowledge. In addition, a level of awareness was identified randomly and the information centers were considered as any suitable information source available. In the initial simulation, each person has a level of awareness that is considered as an awareness point, and we considered a classification based on these scores:

1. 0-5 points: unaware
2. 5-10 points: aware
3. 10-15 points: well-informed

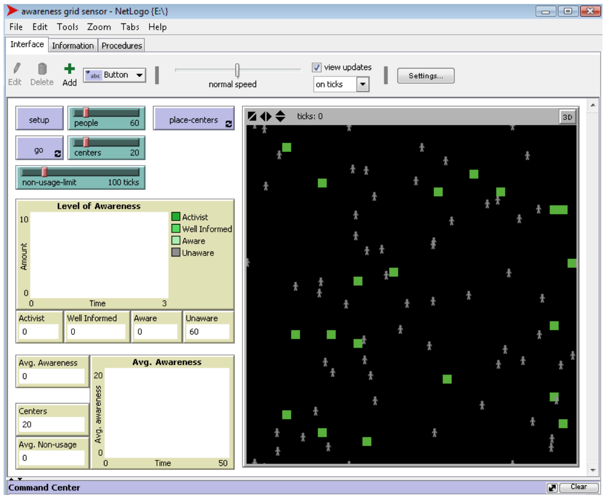

Figure 9: An overview of simulation of sensor-grid's shared awareness in Netlogo Platform

4. Above 15 points: activist

Accordingly, an overview of user's shared awareness is depicted in Figure 10.

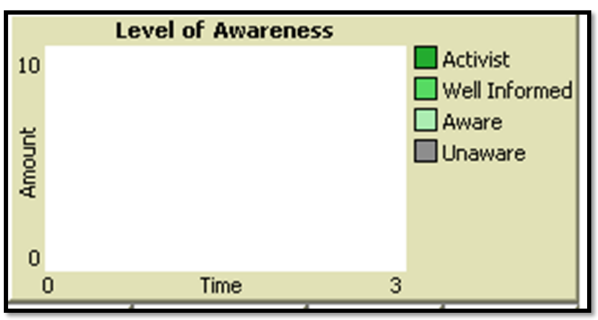

Figure 10: An overview of user's shared awareness

In the environment, the subject sends his request to the source if it receives the correct answer, he will earn 5 points. If he does not receive a response within a specified time, a point will be lowered. (Minimum level of awareness here is set at zero and maximum of 15). If the score level is higher than 15 it is added as a new central knowledge. Given the limited life of sensor resources, we considered the usage limit as data reception source, which can be varied according to different threshold conditions, but it will be terminated at the source level if it is lower than the minimum usage limitation level. The purpose of this simulation was to show the impact of expanding and increasing the number of resources on the level of user's awareness, which is the most important issue in decision making. The criteria to be evaluated were:

1. Number of users: number of participating agents.

2. Number of data resource centers: there is a certain initial amount of resources that, depending on the circumstances, can be increased by the amount of knowledge that can be gained through appropriate interactions and collaboration between network members, resulting in increased resources in simulation. It is intended and, in the event of inadequate collaboration between members, merely reduces the life of the centers, which, in the light of the minimum intended amount for the life of the resources, will eventually be eliminated.

3. Mean awareness level: achievement of a certain amount of awareness between users according to the time.

4. Resources life limit: a time-based threshold level for the resource life length.

At this stage, with the number of users up to 100 and the number of resources by 5 (low), 10 and 20 (moderate) and 40 (high), and the resource life limit of 100/50 ticks, the level of shared awareness among users on the network was examined. An overview of simulated resources and users can be seen in Figure 11.

The results of simulation in diverse modes are presented in Table 1.

Table 1: Comparison of simulation results

	Mean shared awareness		
Resources	[A]	[B]	[C]
5	0	0,055	0
10	0,17	0,225	0,1
20	6,66	13,95	0,25
40	14,97	15	14,94

[A]:number of users=100, resource life limit=100 ticks
[B]:number of users=200, resource life limit=100 ticks
[C]:number of users=100, resource life limit=50 ticks

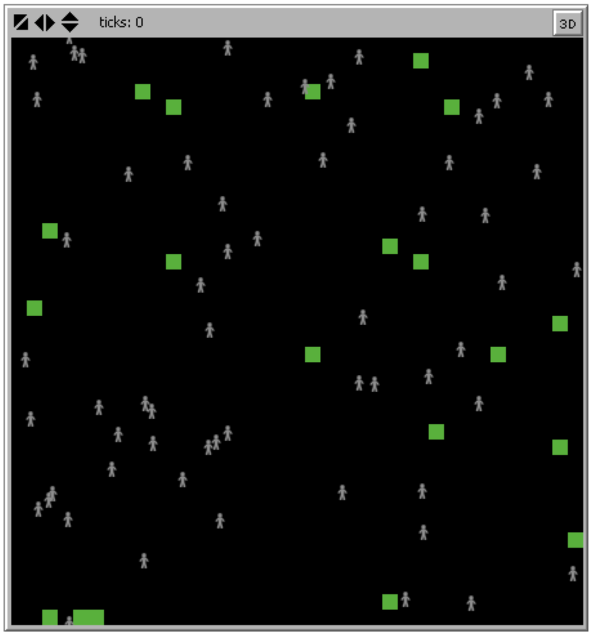

Figure 11: An overview of simulated users and resources

6. Conclusion

The integration of the two technologies of sensor networks and grid computing has many challenges, and much of the effort and research related to middleware, protocols, and network connections have been/will be made. Sensor Grid management must be implemented actively, dynamically, and distributed to enhance consistency and error tolerance. At all outlined frameworks, the challenges of management, security and accessibility mechanisms have been addressed with different perspectives and approaches, and these challenges must be responded through a technology utilizing social and cognitive interactions. By examining the various sensor grid frameworks, we will come to the conclusion that in these architectures the grid is considered as a social network where individuals, machines, and virtual roles are interconnected. In addition, other management systems in the grid, not even referred to as the knowledge grid, are considered as a knowledge-based grid with which the sensor grid interacts. As a result, the Knowledge Grid can be considered a social network that serves as the infrastructure for the Sensor Grid to meet the confidence and commitment for receiving and distributing data. Given the mentioned above explanations, present study integrated sensor networks and grid computing based on OODA intelligent architecture and ELF decision making models. To this end, the simulations were conducted based on CoomonKADS framework at three levels including simplicity, composition and analysis. The results of the simulation indicate that as the number of network elements (resources and users) increases, namely, the large scale performance, the level of shared awareness significantly increases. As the acquired data and knowledge are either stored or retrieved from other sources and given the large-scale resource's life reduction, the findings also show that shared awareness will not be significantly decreased with reduced resource life at a very large scale. The great note about the results is that the best mode of shared awareness is obtained when we have the highest scale of users and resources.

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