A--Broad Agency Announcement for Unmanned Undersea Vehicles

Solicitation Number: N0002405R6309

Introduction:

Broad Agency Announcement N00024-05-R-6309 highlights a few examples of key UUV (Unmanned Undersea Vehicles) technology areas of interest to the Navy. Some of these are serviceable using Compsim's KEEL® (Knowledge Enhanced Electronic Logic) Technology.

"Sensor Integration. A UUV system combines many sensors, which compete for resources and bandwidth and often require careful timing or tuning to operate optimally together. Emphasis is placed on integration of acoustic sensors with DVLs and acoustic communications, along with the integration of antenna-mounted ISR sensors."

"Autonomy. Open architecture autonomy is needed to support long, complex missions in unpredictable or harsh environments. It includes the need to make independent decisions based on the mission goals, environmental conditions, the on-board sensors, and remaining energy. Emphasis is placed on autonomy technologies that could be part of a larger decision-making architecture."

"Computer-aided Detection and Classification. CAD/CAC of targets from UUV sensor data improves capability both for onboard real-time UUV processing and for off board post-processing."

Brief KEEL Technology Overview:

"KEEL Technology" is an umbrella term encapsulating 1) the KEEL "dynamic graphical language" (DGL) that is suitable for capturing, testing, deploying, and auditing complex cognitive models, 2) a model for human-like reasoning that integrates supporting and blocking input signals, 3) a small memory footprint deployment model suitable for deployment in computer (microprocessor) based devices, and 4) a model for deployment as an analog circuit. [1]

Sensor Integration:

A key service supported with KEEL Technology is information fusion. In a UUV, this is will happen at numerous levels as decision making will be distributed throughout the UUV. At the lowest level, it may include simple sensor fusion (perhaps integrating a

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[1] KEEL is patented and patent-pending technology that is licensable from Compsim. It also includes a full set of "tools" to support design, test, deployment, and re-engineering of cognitive systems.

feature sensor with a distance value). At higher levels, sensor / information fusion will integrate multiple preprocessed information items to create collective information packets that are then integrated at even higher levels. Also, sensor integration cannot be done in isolation. It must be combined with situation awareness data to facilitate appropriate decision making and adaptive control. It is also likely that information from a single sensor will participate in several decision-making domains and in each case carry different levels of significance and be integrated with other sensors / information sources / rules of engagement for a variety of applications: target / obstacle interpretation, goal seeking, diagnostics / prognostics. It is also likely that operational state will participate in how the sensor data is interpreted: maintenance state, launch state, approach state, in-route state, damage control, search and rescue, attack… Information fusion / decision-making will be a continuous set of tasks distributed throughout the UUV. It will be orchestrated with interruptible structures much like the way that a human detects change and adapts to those changes. KEEL Technology provides a way to model (create), test, deploy and audit these domains. Using the KEEL DGL, the models can be created without manual "coding" since the "code" is auto-generated by the KEEL tools. The same models can be created in different computer languages (C, C++, Java, C#, Visual Basic, …) so they can be used in training systems based on one language, simulations in another, and deployment in another without re-engineering the cognitive engines.

Autonomy:

The requirement for UUVs to operate autonomously demands that they incorporate the ability "reason" on their own. Reasoning is the ability to "interpret information", and it is required to make decisions. Unlike simple IF | THEN | ELSE logic, reasoning interprets the importance of information and combines multiple pieces of relative (analog) information to make judgmental decisions. These decisions are more complex than just selecting options (Choose A, B, or C). The actions defined by A, B, or C are relative and could be "some amount of A, some amount of B and some amount of C". Reasoning has been said to be more of an image processing function than a pure logical operation; more right-brain than left-brain. KEEL "engines" provide reasoning in a manner similar to how humans "reason". The KEEL engines interpret the importance of information items and then balance the entire cognitive model to obtain the best overall response for the "system". To achieve "autonomy" the UUVs will be goal seeking. Their rules of engagement will describe boundaries for their actions and describe how they should function in a dynamic environment. In one mode they will be operating completely independently and in another, they will be operating as part of a team (with and without humans in the loop). They will "share" information with other UUVs and actors in the team. They will incorporate information from other sources (other UUVs, human peers, and from an intelligence hierarchy). From a KEEL standpoint, all of these data items are just that: data items. Each will be treated and evaluated according to rules of engagement. The KEEL DGL provides a way for defining complex, dynamic, non-linear, multi-dimensional, inter-related rules that are completely explainable and auditable. The ability to "audit" subjective behavior is a mandatory feature for these types of devices as they will be expected to perform in complex, potentially life-threatening situations.

While UUVs are expected to operate autonomously, they must still be under the control of humans. One approach would be to give the UUVs direct commands. This, however, may not allow the UUVs to utilize their real-time view of their environment. A more appropriate approach would be to allow the command hierarchy to exert control over the UUVs by “controlling how they interpret information” or “controlling how the UUV interprets risk”. KEEL Technology supports this model by allowing configuration parameters (other data items) to control the interpretation of information.

Since UUVs are expected to operate autonomously and pursue goals on their own, they can benefit from the incorporation of some human-like characteristics. One example is the human emotional characteristic of “frustration”. A UUV will often have a goal that can be accomplished in multiple ways. In a particular instance, the “preferred approach” may prove unacceptable for some reason. After attempting to achieve the goal several times using the primary approach, the UUV might use a “frustration model” to select an alternative solution. Compsim has incorporated frustration in UAV (Unmanned Aerial Vehicle) models.

Computer-aided Detection and Classification:

A focused extension of Sensor Integration is the integration of information to detect and classify targets. In this case, sensors provide a feature extraction function and KEEL “interprets” the features by combining the available data items and comparing them against a library of features. This is similar to the application of KEEL to interpret medical symptoms to determine a disease. Confidence levels can be provided in a way that is completely auditable. Thresholds can be used to trigger actions when a target is sufficiently identified.

Summary:

The KEEL DGL allows the creation of complex models without resorting to complex mathematics. This allows models to be created and tested by solely by domain experts rather than requiring iterative collaboration between domain experts, software engineers and testers.

KEEL Technology is a system level cognitive technology suitable for addressing complex multi-dimensional problems. The KEEL DGL allows one to “see the devices think” by showing how the data items interact to changing environmental values.

Contact:

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