Judgmental Aspects of Autonomous and Semi-Autonomous Devices

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Introduction:

Interest in autonomous and semi-autonomous vehicles and devices has escalated in recent years. Much of the interest in autonomous vehicles has been fostered by considerations for Future Combat Systems (FCS) targeting robotic forces and by Homeland Defense systems targeting surveillance and reconnaissance activities. In support of these initiatives, C4ISR developments are focusing on the dissemination of information so that coordinated missions can be accomplished. While the general category of C4ISR technologies is meant to address human systems, they must equally address autonomous and semi-autonomous devices. In the past few years there have been many examples of robotic vehicles. Unmanned aerial vehicles (UAVs), autonomous underwater vehicles (AUVs) and autonomous surface vehicles (ASVs) have been created in a variety of shapes and sizes to target specific applications. In Japan, research into human-like robots that can eventually provide support for an aging population is being pursued. In support of these devices, new sensor technology is being developed to assist the devices pursue their goals.

One key technology that is still in its infancy is the cognitive portion of the devices. While conventional programming techniques remain the primary approaches for controlling these devices, they will not provide the necessary services for the devices to accomplish the expectations that are being defined for them. Only by adding judgmental capabilities to the devices will they be able to “reason” and pursue goals without humans being tightly coupled with those devices. When FCS concepts suggest a single human may control multiple semi-autonomous devices it will be necessary that those devices operate with a large degree of autonomy. This means they will not just be performing scripted actions. They will have to be able to evaluate their own environment and react on their own to achieve the goals set by the enterprise. This will require “judgment”.

Judgmental Decisions:

It has been suggested that the human brain processes information with the left hemisphere processing language, numbers and logic, and with the right hemisphere processing images and judgment. Image processing and judgment requires the “interpretation of information” and the “balancing of that information” while taking into account “inter-relationships” that might exist between information items. This is an analog process that allows a human to rapidly react to changing information and adapt to the environment. Using these analog techniques, humans are able to pursue goals even when they have to react to change. It is important to understand that “how” they pursue their goals is perhaps more important than the continuously changing intermediate goals that might develop.

So, when we expect devices to operate autonomously or semi-autonomously, they too will have to adapt to their environments. They will have to choose between optional actions. And the actions, themselves, will be relative to the situation; not just on or off.

Example:

A simple example of judgmental decision-making is shown below. Each UAV has its own cognitive KEEL® (Knowledge Enhanced Electronic Logic) engine. Each UAV is hunting for the target (identified by the blue marker). It is constantly evaluating its situation: fuel supply, weapons supply, nearby threats, the other UAV (for collision detection), directives from above… When it finds the target, it evaluates the target value and associated risk. As it evaluates its situation, it determines whether it should take an evasive maneuver, try to hide, maneuver around the other UAV, attack, or go home (retreat). It performs these actions by interpreting its environment and making a judgmental decision about what to do and how to do it. If it decides that an attack is appropriate it then makes a judgmental decision about the optimal time to shoot by balancing the risk against the reward. Should an unexpected threat come about during the attack, the UAV will re-evaluate the situation and react accordingly.

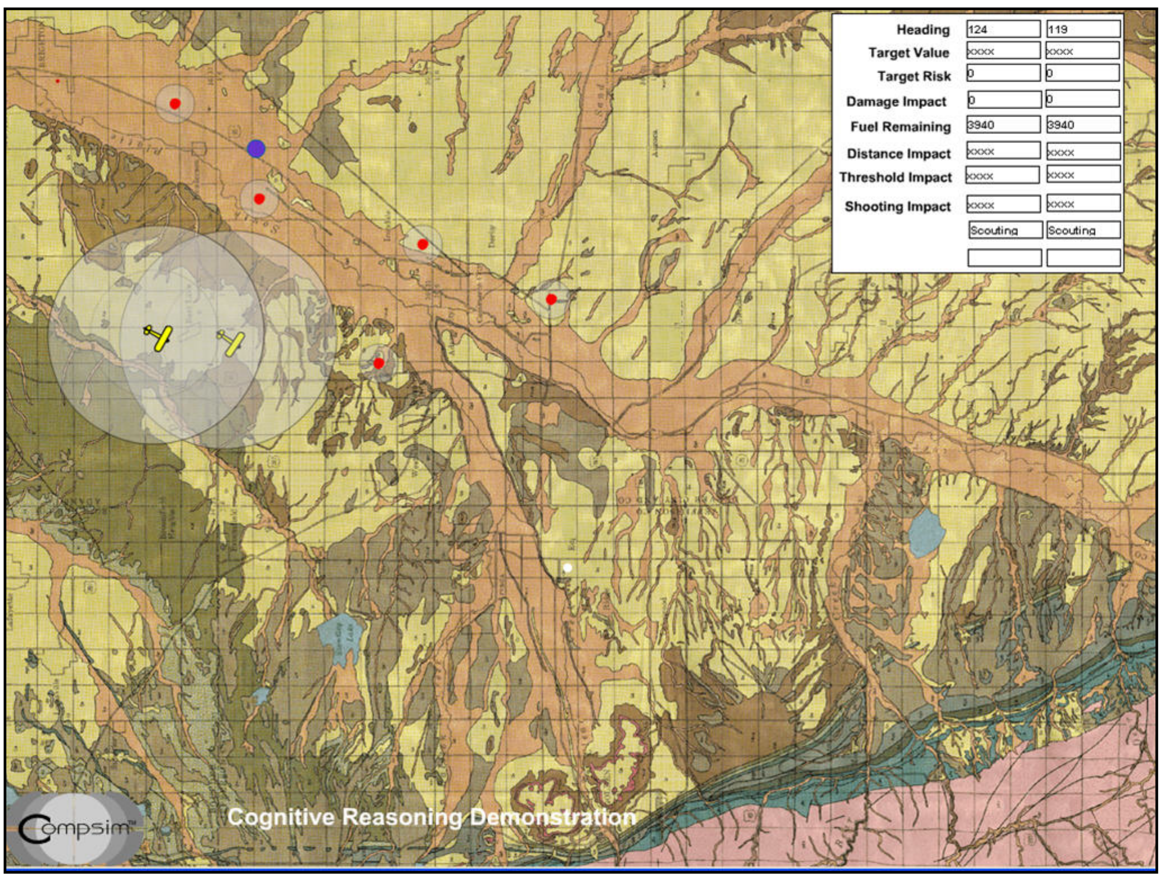

Figure 1.
An explanation of the demonstration is provided at the end of this document.
Interactivity is only provided when viewed with Adobe Acrobat 6 and above.

Control of Autonomous and Semi-Autonomous Devices:

Because these autonomous devices will have their own “rules of engagement” that tells them how to interpret and balance information, it is not appropriate to operate them as purely remote control vehicles. This would fail to take advantage of the intelligence available to those vehicles that is available to them in real-time from their own sensors. On the other hand, there will be cases where external intelligence is available that is not available locally to the autonomous vehicles. In these cases it is important that intelligence is made available to the remote vehicles. This can be accomplished by providing information to the remote vehicles that allows them to include the new information in their decision-making process. This can be shared information between autonomous vehicles or it can come from a higher authority. This new information will then be included in the judgmental model of the autonomous vehicles. This same process can be used to completely control the autonomous vehicle if this is deemed appropriate. This process allows the autonomous vehicle to follow the rules of engagement, still make use of local real time information, and still allow a higher command authority to provide direction.

Audit Trail:

A key factor in the acceptance of autonomous vehicles and autonomous devices is the confidence that we have in their actions. In this light, it is mandatory that the decisions and actions of these autonomous devices are completely explainable and auditable. Because we will be expecting these devices to make judgmental decisions relative to complex dynamic, non-linear, inter-related problem sets, we cannot just assume that the defined policies are correctly handled. This is especially true when we are dealing with life and death situations and safety critical decisions. When an evaluation of collateral damage, or risk to the autonomous device itself, becomes part of the decision-making model, it will be mandatory that the model can be audited. This is somewhat similar to the “black box” included in commercial and military aircraft. In this case, however, the autonomous device may make a decision not to proceed with a goal. So it is not just to audit an action, it may be to audit an inaction or any unexpected action taken by the device.

Summary:

It is now possible to create judgmental models for use in autonomous devices that provide completely explainable decisions and actions. It is likely, however, that the creation of fully autonomous vehicles and devices will be an evolutionary process. When complex problems have been addressed with human systems, we benefit from the human’s native ability to balance commands from above with the reality of the situation. With humans, we accept varying levels of performance. When we begin mass producing autonomous vehicles and devices, however, we expect them to perform exactly according to pre-established rules. And because they will be mass produced, the potential for mass producing a product with “poor judgment” has to be of concern. For this reason, completely explainable and auditable products will be required.

Interactive Demonstration:

- The blue dot is the target for the UAVs.
- The red dots are defensive sites that can inflict damage on the UAVs.
- Neither the target nor defensive sites are visible to the UAVs until they get close to them.
- Each UAV operates completely independently and takes random headings while searching for the target.
- Each UAV is constantly monitoring its damage assessment, fuel supply, threats, target value, target risks… and determining what it should do (built into the KEEL cognitive engine).
- Each UAV has its own collision avoidance model (build into the KEEL cognitive engine) to avoid running into the other UAV.
- When a UAV finds the target is worthy of attack, it determines the optimal time to shoot by balancing the target value and associated risk. It may decide not to attack at all based on its “rules of engagement”.
- The user can interact with the demonstration by clicking his/her mouse on the map. UAV1 will fly toward the left-click point. Shift-left-click will control UAV2.
- When a UAV fires its missile it will return home and the target and defensive sites will be reset randomly. The other UAV will continue its mission.

NOTE: The KEEL Engines for these UAVs were created with Compsim’s KEEL Toolkit, where the models were deployed as Macromedia Flash code for integration in the Macromedia Flash MX development environment. The same KEEL Engines could be deployed as C, C++, Java, Microsoft Visual Basic, VB.NET, C#, or PLC Structured Text, for integration in other platforms.