Draper Input to LIDS Symposium Panels

Introduction

Draper Laboratory is pleased to present a list of challenges that our customers are facing in a variety of topic areas covered under the information and decision system panel subject areas of this Symposium. For each challenge we provide a description of our perception of some relevant aspects of the challenge. This is followed by a sketch of some of the potential opportunities achievable if progress can be made on these challenges. We would welcome any questions or further discussion on these topics.

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Control & Optimization

Reliable, Robust, and Trusted Automation & Decision Systems

Challenges:

Develop a unified approach to the design, implementation and test of decision systems that will be readily accepted by users.

Reliable: Tools and approaches exist for analyzing and designing systems to achieve system hardware reliability including design tradeoff and sensitivity analysis, but similar capabilities for software reliability are more limited.

Trusted: 1. Systems designed to understand the operator's needs and objectives. 2. The operator understands why the system has chosen what it will do and how it will accomplish it. 3. The operator is assured that the system will *do no harm*. 4. Perhaps the most difficult, a system that is able to act as a true *team member* in collaborating with the operator in achieving mission objectives.

Robust: Here robustness pertains to uncertainty in knowledge of elements of the operational environment that cannot be known with certainty ahead of time – including weather, terrain, other actors, especially adversaries, as well as system models.

Opportunities:

Opportunities for transition to operational users will come with increased user acceptance of automation and decision support systems. This acceptance will come as a result of an increase in user's trust in those systems to respond in a manner that addresses the user's intent and in a manner that is robust to the vagaries of real-world operational conditions.

Intelligent Behaviors for Unmanned Vehicles

Challenges:

Design challenges include approaches that address intelligent behavior at two levels of control: 1. Ensure commander's intent is achieved in plans composed of multiple activities. 2. Perform individual complex activities (e.g., search an area). System level objectives include developing (a) a language that can unambiguously capture commander's intent (e.g., objectives) and Rules of Engagement (e.g., constraints) and (b) onboard intelligence that is able to respond to these objectives and constraints more like a team member than a robotic subordinate. The challenge encompasses both individual vehicles and cooperative multi-vehicle systems.

Opportunities:

Operational benefits include: reduced bandwidth requirements and operator workload, enabling more complex mission capabilities, and increasing mission effectiveness beyond that achievable through a human supervisory relationship.

Dynamic Large Scale Optimization / Collaboration Across Stovepipes and Echelons

Challenges:

Many realistic systems of interest are distributed and asynchronous, and the subsystems are managed as separate entities. Stovepipe operators are reluctant to support system-level objectives that do not have clear local benefit.

Opportunities:

Design and efficient operation of Earth observing science missions, especially for climate change is one application area of interest. Another application area is improving information flow and synthesis between front-line soldiers and higher echelons, as well as across echelons. Technology to help facilitate the transfer of information gained by front-line soldiers to those who follow or replace them is also of high interest.

Intuitive Operator Tasking and Analysis of Systems / Synergistic Human – Computer System Operations

Challenges:

Machine intelligence is different than human intelligence, resulting in frustration for many users and puts limits on realizing the potential benefits of automation technology. Integrating automation technology does not usually result in the sum of the strengths of the machine and human intelligence. Thus there is a challenge in designing systems that account for the differences between human and computer intelligence, systems that perceive the cognitive state of the operator, understand the context of the current situation, and that can provide human operators relevant information about the basis of decisions or recommendations. Successful synergistic operations provide the opportunity for the development of trust in the automation, making the users more apt to adopt and make use of the technology.

Opportunities:

There are many applications that would benefit from embedding intelligence into the system to work with humans in a more natural way, and to adapt to evolving situations and evolving user needs. Additional opportunities include solving complex optimization, planning, and analysis problems. Data communication between an operator and remotely located collaborators is often limited, and there is a growing need to transmit only the relevant information in a timely manner.

Networks & Information

Models for Predicting and Influencing Social Networks

Challenges:

Identifying models that describe the interactions and dynamics of real world social networks is difficult due to the partial observability of data and the uncertainty due to human behavior. For a model to be effective, an integrated approach using social and physical sciences is needed.

Opportunities:

Potential opportunities include business applications, education, public health, counter-terrorism, and nation-building and stabilization operations.

Networked Management and Control of Assets

Challenges:

Military and commercial enterprises are driving toward increasing levels of net-centricity. The changes will require new paradigms for control, estimation, and coordination. Particular challenges include overcoming dimensionality, non-traditional communications structure, reducing bandwidth requirements, large-scale data fusion and pattern detection, and providing situation awareness.

Opportunities:

There are many emerging opportunities for architecting the next generation System of Systems (SoS) for networked assets. There are also opportunities for "asset agnostic" C4I algorithms and applications ("cloud computing" and "network application" for unmanned systems).

Reducing Power Consumption of Communications in Miniature Electronic Systems

Challenges:

As electronics continue their path toward increasing miniaturization, optimizing power consumption increasingly becomes a paramount objective. In the case of wireless information transmission, how should traditional paradigms such as the source-channel separation theorem be recast? From a system perspective (i.e., to include antenna, sensor, signal processing, RF front-end, etc.), where are the opportunities for breakthroughs?

Opportunities:

The drive towards the miniaturization of wireless sensors will continue. Technology that can reduce power consumption from communication subsystems of miniature devices will continue to be of high interest.

Estimation, Inference, and Learning

Discovering Patterns of Behavior and Predicting Actions from Large Datasets without Pre-existing Hypotheses

Challenges:

Advances in sensor technology, communications, and information technology have greatly expanded the quantity and type of data available for analyzing a specific problem or issue. The diversity of information is often categorical or descriptive in nature, rather than quantitative. Relationships and association among entities can be the key information for unraveling a problem. Understanding and characterizing normal relationships and behaviors can provide a basis for detecting anomalous patterns, which could indicate a problem or a threat. Often the nature of the threat is not known *a priori*. Methods that can discover and model underlying patterns in large, diverse data sets are needed to characterize normal behavior and detect departures from normalcy that merit investigation.

Opportunities:

Success in this area would enable solutions to a number of problems in the understanding of large, diverse systems, including detection of intrusions in computer networks, analysis activities associated with improvised explosive device (IED) events, monitoring of illicit cargo or drug trafficking, and detection of impending failures in large power grids.

Perception / Situation Awareness for Unmanned Vehicles

Challenges:

Increasing autonomous capability to perceive and understand the operational environment, ranging from inanimate elements (e.g., terrain, weather) to intelligent entities (friend, foe, neutral). Technical challenges include sensor design and selection, real-time signal processing, and drawing mission-relevant inferences from the situation. Emphasis is on computations that can be carried out onboard.

Opportunities:

These advanced algorithms along with reductions in size, weight, and power (SWaP) will enable more intelligent autonomous vehicles. This will allow more complex and longer duration missions to be performed fully autonomously benefiting both the scientific and military communities.

Human Learning Capability as a System Component

Challenges:

Designing systems that work to increase relevant human expertise as part of an adaptive decision support function has significant challenges. Such a system would understand the differing levels of expertise of each human operator and provide a tailored program to increase their knowledge, while performing the core system function. In addition, as the operator builds experience with the system, the system gradually reveals its capabilities, providing an opportunity for the operator to use the system in ways that it perhaps was not initially designed for or the operator did not initially understand.

Opportunities:

A personal assistant that teaches while performing mission tasks would have very broad application. This will change the trend from increasing human dependence on decision support and decreasing human insight into the system, to empowering operators through the decision support process. A key need will include the development of a system that can continue to operate outside of its intended envelope, providing users with an extensible tool.

Robust, Reliable Navigation for Real Operational Environments

Challenges:

GPS and GPS/INS navigation systems for many applications do not provide the desired level of robust performance in complex terrain. When fusing additional sensor information, the Kalman filter formulation is at odds with the design objectives. A filter formulation is needed that fuses diverse information sources with errors that are uncertain, have jump behavior in time, and that seek to achieve acceptable performance (not minimum variance) while being robust to sensor performance variations.

Opportunities:

There is a large potential market for the next generation of personal navigation systems for both commercial and military use. This next generation is likely to include systems that work in urban, indoor, under tree canopy, and underground environments. There are opportunities to develop and utilize new sensors and information sources. Fusion of these new sensors also opens up opportunities to augment or replace Kalman filters for this next generation of navigation systems.