Intelligent Sensor Fusion for the 1997 AAAI Mobile Robot Competition

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Introduction

The Colorado School of Mines (CSM) will field a team of undergraduates for two events in the 1997 AAAI Mobile Robot Competition: *Life on Mars* and *Hors D'oeuvres*. The objectives of the team are (1) to gain experience with implementing behaviors under a hybrid deliberative/reactive style of architecture and (2) to transfer research being conducted at CSM in intelligent sensor fusion to new applications. The students are preparing the entries as part of the class projects for the MACS415: Introduction to AI Robotics and Computer Vision and MACS370: Field Session courses. The team is using two different robots, both running subsets of the Sensor Fusion Effects (SFX) architecture implemented in C++.

The term intelligent sensor fusion denotes a broad characterization of sensor fusion, dealing with how observations from one or more logical sensors can be combined reliably into a coherent percept. Two components of our research in intelligent sensor fusion are being applied to the competition. The first component addresses how to combine the observations from multiple sensors into a percept and generate a measure of belief. This is a key element of the sensing strategy for the Hors D'oeuvres event, where evidence from simple features (audio, motion, and flesh colored regions) are combined to produce a measure of belief in the presence of a person. Our approach is an adaptation of (Goodridge 1996) for a Dempster-Shafer evidential scheme.

The second component deals with combining sensor observations over time. This is an important aspect of our approach to the Find Life on Mars event, since a suspected Martian may disappear due to a temporary occlusion, because it has attempted to hide, or the sensor reported a faulty observation. In order to successfully balance resources (energy, time) with the goals (find Martians), the robot must persist in its belief that it saw a Martian for some period of time in order to continue searching, but it must eventually give up if it cannot reacquire the target. The problem is exacerbated by the lack of explicit *a priori* models of the Martian to guide a model of persistence. Our approach is to use an alternative formulation of Dempster's rule of combination to decay the belief over time in a principled fashion (Murphy, Hawkins, & Schoppers 1997) using only directly perceivable attributes.

SFX Architecture

The teams use the Sensor Fusion Effects (SFX) architecture (Murphy & Arkin 1992) as a framework. Fig. 1 gives a simplified system overview. It is a hybrid architecture, most similar to AuRA (Arkin, Riseman, & Hansen 1987) with some attributes of the 3T (Bonasso & Kortenkamp 1995) partitioning of responsibilities. The deliberating member of the deliberative layer handles all activities which require knowledge about, and control over, the robot's task. The managerial portion has access to global knowledge about the state of the active behaviors and the environment but may not preemp tasks. The Sensing Manager and Task Manager agents work together to maintain task progress; they can identify and replace failed logical sensors or behaviors. The *reactive*, or behavioral, layer is responsible for executing the behaviors according to the plan. Behaviors are either *strategic* or *tactical* (Murphy & Hawkins 1996). Collections of concurrent and/or sequential behaviors which occur frequently are encapsulated into an *abstract behavior* (Murphy 1996), which coordinate and control primitive behaviors via scripts.

Find Life on Mars Event

The team will use a custom built mobile robot, *Silver Bullet*, for the Find Life on Mars event. *Silver Bullet* has been built from scratch as part of an NSF Research Experience for Undergraduates (REU) program at CSM in autonomous mobile robots for Urban Search and Rescue. The robot has six sonars, three in front, 2 on each side, and one in back, for obstacle avoidance; a color camera on a panning mast for general vision; a E^2T thermal probe for heat detection; inclinometers for navigation in rugged terrain; and a global positioning system (GPS) board. It is controlled by an on-board 133MHz Pentium PC.

The team is using a subset of the behaviors and sensing strategies developed by the REU participants for more general Search and Rescue applications (e.g., searching for signs of survivors after an Oklahoma City bombing). The *search* behavior is based on how animals search and forage, and uses a novel organization of robotic search software developed by (Murphy & Sprouse 1996). *Search* has four components: a *search controller* which computes the win-stay or win-shift decisions based on the operator's input, a *navigation behavior* which has the robot maintain the desired search pattern, a *scanning behavior* which controls how the sensors mounted on the robot scan for targets and actually detects the targets, and an *examination behavior* which attempts to position the robot and/or sensors in the best view to examine or capture the target.

Hors D'oeuvres Event

The team expects to use a Nomadics XR-400 mobile robot for the Hors D'oeuvres Event. The robot will be equipped with sonars and infrared sensors for long- and short-range sensing of people and obstacles. Two microphones mounted on the sides of the robot will be used to detect and localize loud noises. A color video camera will provide vision data.

The navigational behaviors for this task are limited, given that the robot is expected to operate in a crowded room. The success of the "natural" interaction of the robot with audience depends on the sensing to disambiguate people from other objects in real-time. The sensing strategy is to use audio, range, and visual motion detection to identify a potential person. Individually, each of these observations are sources of weak evidence; however, they can be used to focus the attention of a computationally expensive but more reliable vision algorithm which examines the image for flesh tones (Goodridge 1996).

Acknowledgments

This research is supported in part by NSF Grants CDA-9617309, IRI-9320318, ARPA Grant AO#B460, NSF REU Site Grant CDA-9531730, and NASA/JSC Contract NAS.9-19040. The team would like to thank Dr. Michael Kay and Steven Goodridge for their code and advice.

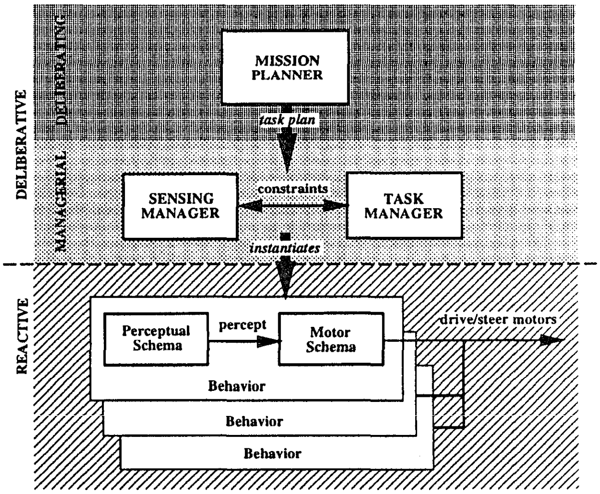

Figure 1: Overview of the SFX architecture.

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