Visual motion control in flies and fly-sized robots

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This demo session will include exhibits on visual control of motion targeted at fly-sized robots. It consists of the following:

1. Displaying a physical robot that rolls in a two-dimensional world and navigates through confined spaces using only visual cues. The optic flow algorithm it uses, autocorrelation or the "Reichardt Correlator" is inspired by studies on the behavior of insects' visual autopilots. This optic flow algorithm imposes minimal onboard processing requirements, and thus is ideal for a computationally-constrained fly-sized vehicle. This demo will include a video on a laptop showing this vehicle in operation.

2. A display prototype of a fly-sized robotic vehicle, a "Robobee", that flies by flapping its wings using a piezo electric actuator. Along with this display prototype will be a video of the vehicle – which is normally unstable without active feedback, much like a jet fighter – being stabilized using visual feedback from four light sensors. These four light sensors detect the vehicle's orientation relative to a luminous sky or sun. They are inspired by three light sensors, the ocelli, that are distinct from the compound eyes and lie at the top of the head of most flying insects.

3. A display of trajectories taken from the flight paths of fruit flies *Drosophila melanogaster* subjected to sudden impulsive gusts of wind. These trajectories were taken from a study of how their flight speed regulator incorporates input from both the visual system and the antenna-mediated wind sense to robustly control forward velocity.

Exploring Underwater Environments with Curiosity

Yogesh Girdhar and Gregory Dudek

I. Introduction

The attached video [1] illustrates our work on vision-based information-seeking as applied in the context of underwater robotics. The video shows an Aqua2 amphibious hexapod swimming through the ocean searching for visually interesting context. The search and modeling of novel content, that is, curiosity, is a fundamental characteristics of most intelligent systems, and is one of the universal attributes of intelligent species.In the robotics context, we would like robots to plan exploratory path through the environment, which would allows it to efficiently learn about new and different scene constructs such as objects and terrains. We demonstrate an implementation of such a system.

II. Approach

The underwater robot is equipped with a wide angle camera in the front, and the captured images are processed by a realtime online topic modeling framework (ROST)[1], which extracts low level visual features in these images and gives them topic labels, representative of high level scene constructs such as corals, plants, diver and rocks. Low level visual patterns which commonly occur together in space and time, and more likely to be given same topic label. ROST works by placing Dirichlet prior over topic distributions in spatiotemporal regions in the video stream, and using a realtime Gibbs sampler to keep the topic model in a converged state. Now, given the description of the current scene in topic space, the robot then identifies the part of the scene with most novelty. We use a winner-take-all strategy to determine this area of attention with maximum information gain, and then navigate the robot laterally in the direction of this point.

Let $\theta^t(k)$ be the probability of seeing topic k in the world after t time steps.

$$\theta^t(k) = \mathbf{P}(z_i = k|\alpha) = \frac{n^k + \alpha}{\sum_{k=1}^{K}(n^k + \alpha)}, \quad (1)$$

where α is the Dirichlet prior for the θ^t, and n^k is the number of time topic label k has been observed, and K maximum number of topics modeled by the system. The amount of information we have gained thus far can then be measured by computing the entropy of topics labels in the current topic model:

$$H(t) = \sum_{k=1}^{K} -\theta^t(k)\log\theta^t(k) \quad (2)$$

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[1] http://cim.mcgill.ca/~yogesh/publications/nerc2013.mp4

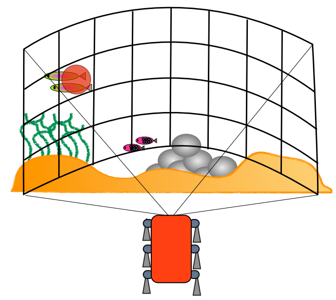

Fig. 1. The robot explores the environment by finding novel observations, while building a topic model of its experience.

Given an unknown environment, we would like to plan a path through it such that $H(\theta^t)$ is maximum. We do this by greedily turning toward the cell with most information gain defined as:

$$S(i) \quad = \quad d_{\mathrm{KL}}(\theta_i^{t+1} \| \theta^t), \quad (3)$$

where θ_i^{t+1} is the posterior topic distribution of the model, if we just observe the ith cell, and $d_{\mathrm{KL}}(.\|.)$ is the KL-divergence between the two distributions. This formulation of curiosity is consistent with the idea of Bayesian surprise proposed by Itti et al [2].

III. Results and Conclusion

The emergent behavior shown in the video has a striking similarity to that of biological organisms. The video shows the robot in three different scenarios. In the first, scenario, the robot begins exploration near a coral head. We see that the robot quickly gets attracted towards the coral head, and continues to bounce around over this structure while staying away from sand with relatively little novel information. In the second scene, we see that as soon as the diver is in robot's view, it is the singular source of curiosity for the robot. We see the robot following the diver around, and hovering over the diver when he has stopped moving. In the third scene we see the robot explore a sparsely populated ocean floor. We see the robot manages to keep its focus on sea life, while not wasting time over sand.

References

[1] Y. Girdhar, P. Giguere, and G. Dudek, "Autonomous Adaptive Exploration using Realtime Online Spatiotemporal Topic Modeling," *International Journal of Robotics Research (Accepted)*, 2013.

[2] L. Itti and P. Baldi, "Bayesian surprise attracts human attention," *Vision Research*, vol. 49, no. 10, pp. 1295–1306, 2009.

Sensing and Compliance in Grasping and Manipulation

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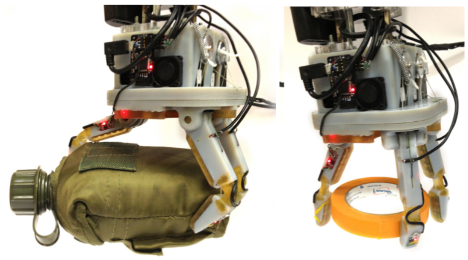

The development of low-cost hands is critical for creating affordable robots for household chores and elder care, improving the capabilities of telepresence robots, and providing better robotic disaster relief. Compliance and underactuation simplify the control required to grasp a wide range of objects by passively adapting to variations in object geometry and object shape.

However, it has been difficult until now to integrate low-cost tactile sensors due to systems-level concerns such as sensor cost, manufacturability, and wiring. Recent advances in MEMS barometer technology provides a low-cost, robust approach to create tactile arrays with sensitivity in the 0.01N range and sampling rates 50-100Hz.

We present a demo of a grasping system based around the i-HY Hand, a low-cost mid-complexity hand created for the DARPA program Autonomous Robotic Manipulation- Hardware in collaboration with iRobot and Yale University. Experimental results show that integrating both compliance and tactile sensing to compensate for positioning errors improves the ability to grasp a wide range of object sizes and masses.

NarwhalEdu Demo Proposal
Northeast Robotics Colloquim 2013
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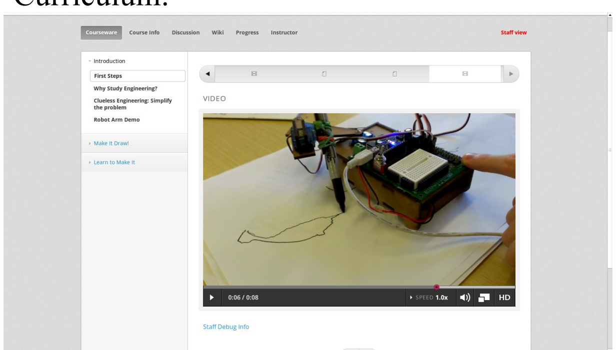
Imagine Khan Academy with hardware project kits. We are combining online curricula with hardware kits to teach introductory engineering topics at the high school and up level.

To do so, we are using the edX platform (edx.org) and then developing hardware modules. The first includes a drawing robot: a robot arm that draws and is used to teach an introduction to engineering course.

We are three just-graduated engineers who want to increase the number and diversity of students interested in engineering by showcasing it's creative side. We want to inspire high schoolers to see engineering as we do — something fun and wicked cool.

For the demo, we would like to showcase our arm operating with a mock secondary control arm and potentially operating in interactive mode on the computer (where you can draw on the screen and the robot arm will trace out the drawing on paper).

Curriculum:



(left) kit diassembled   (right) assembled kit

A robot avatar for remote participation in laboratory courses

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A novel idea of the project is to offer a distance education laboratory experience through robotic telepresence. This is based on the premise that a distance education student will have a worthwhile experience if he or she may:

- Interact meaningfully with laboratory group members to discuss and exchange information;
- Hear and see the laboratory in progress through a vantage point under their own control;
- Share the challenges of physical preparation of experimental equipment by participating in real-time;
- Contribute to the effort of developing the laboratory report through correspondence and the sharing of data;
- Freely explore the electro-mechanical details of the laboratory apparatus through self-directed observation;
- Share collective triumphs and frustrations of the group effort by being an active group member.

We have developed a robotic avatar intended to operate in unstructured, human-filled laboratory space under remote control. The platform is a Pioneer AT – 3 skid steering mobile robot augmented with a laptop, lightweight extruded aluminum framing to position the laptop at waist height relative to standing humans, a USB camera with Pan Tilt Zoom capabilities, sensors and bumpers designed to allow safe operation in the target environment.

We will bring the robot on-site for modest demonstrations of the instability problem. The poster will highlight the most recent research activity (summer of 2013) including:

- Analysis of the obstacles the robot's environment and the incorporation of tilt sensors to allow safer interaction
- Design and implementation of touch-sensing bumpers allowing robust operation in an obstacle-filled environment
- Description of a motion instability problem induced by pivoting the robot using skid-steering on carpeted or non-smooth floors
- Development of a solid model for analysis of unacceptable vibration induced by skid steering pivoting
- Development of a passive dynamic damper to reduce vibrations during skid steering pivoting