

Exploring Vision as a Basic Navigational Sensor



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Key Ideas

The growing capacity of embedded processors and rapidly improving performance/cost ratio of digital cameras makes mobile computer vision systems more attractive than ever before.

Here we fit off-the-shelf vision components (webcams and Intel's OpenCV computer vision library) to a simple robot to explore the viability of vision for local navigation.

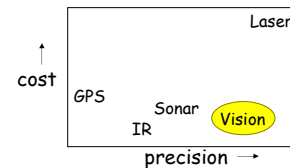
Initial results have been promising: We achieve robust 0.5% linear accuracy and 3% angular accuracy with weakly calibrated, commodity hardware and well-known CV techniques.

Comparing Sensor Costs

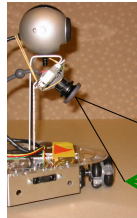
(ignoring cost of computation)

Dimensionality	Type	Unit Cost
0-D	Infrared RANGER	\$10-20
0-D	Sonar RANGER	\$40-80
1-D	Scanning Laser RANGER	\$5000+

2-D 640x480 Camera \$20-80



Speed / Distance

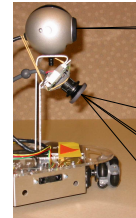


Knowledge of camera angle and height, plus an assumption that the floor is flat enable us to calculate distance traveled via simple geometry.

Apparent path of a feature as the robot moves

To make the calculation more robust in the presence of feature-tracking errors we prefilter feature paths based upon direction of apparent movement, then take the median speed indicated by the remaining paths.

Direction of Travel



Distant features (> 10' away) serve as stable angular reference points during long movements.

During robot motion, nearby features plot paths which intersect at a point on the horizon known as the point of emergence. That point is a high gain but noise-prone measurement of camera-relative robot motion and can be used to fine-tune motor control in response to changing conditions (wheel slip, small obstacles). Meanwhile, features which are further away provide stable, noise-resistant angular references over longer distances.

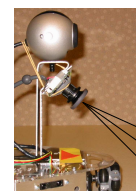
Global Location and Orientation

Distant feature constellations provide stable environment-relative orientation references. Together with a map of the surrounding terrain, triangulation can then be used to determine robot/camera pose.

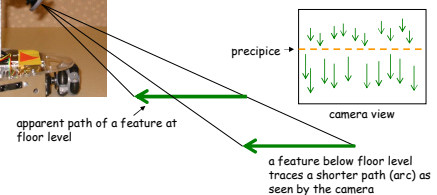
Swappable Feature-Tracking Subsystems

Our work so far uses the image-pyramid-based Lucas-Kanade feature tracking implementation included in OpenCV. Other algorithms can be easily substituted (SIFT, PCA, ...) to take advantage of new developments in computer vision techniques.

Precipice Detection



Floor-level features should all appear to trace paths of the same length*. An abrupt decrease in the length of observed paths can be used to detect and avoid driving off a precipice. (stairs, table edge, etc.)



(* the same length after correcting for camera perspective)

Future Work

- Cooperate with static camera systems (Irisnet nodes, security cameras)
 - Extend the range and resolution of a static camera system with mobile cameras
 - Use static cameras to assist navigation in dynamic environments
 - Automatically calibrate static camera systems with help of mobile platforms as reference points
- Actively participate in dynamic environments (safely interacting with people and machines)
- Share multiple cameras between navigation and other tasks
- Automatically map features usable for global navigation

Research at Intel