Winning the AAAI Robot Competition

David Kortenkamp, Marcus Huber, Charles Cohen, Ulrich Raschke, Clint Bidlack, Clare Bates Congdon, Frank Koss, and Terry Weymouth

Artificial Intelligence Laboratory
The University of Michigan
Ann Arbor, MI 48109
korten@engin.umich.edu

Abstract

Last summer, AAAI sponsored a mobile robot competition in conjunction with the AAAI-92 conference in San Jose, California. Ten robots from across the country competed in the competition, with CARMEL from the University of Michigan finishing first. CARMEL is a Cybermotion K2A mobile platform with a ring of 24 sonar sensors and a single black and white CCD camera. For computing, CARMEL has three processors: one for motor control, one for sonar ring firing and one executing high-level routines such as obstacle avoidance and object recognition. All computation and power is contained entirely on-board.

The competition consisted of three stages, all taking place in a 22m by 22m arena. The first stage involved roaming the arena while avoiding obstacles (cardboard boxes) and wandering judges. The second stage involved searching for 10 distinctive objects and then visiting each of the objects. Visiting was defined as moving to within two robot diameters of the object. The robots had 20 minutes to perform this task. The third stage was a timed race to three of the objects found in stage 2 and then back home. The arena boundaries were defined by walls, and the arena floor was strewn with obstacles. Objects were ten foot tall, three-inch diameter poles. Teams could attach their own tags to the poles to allow their sensors to detect them. The objects could be seen above the obstacles, while the clearance between obstacles was a minimum of 1.5m.

Obstacle avoidance on CARMEL is done solely with its sonar sensors and has two components: (a) a unique method for detecting and rejecting noise and crosstalk with ultrasonic sensors, called error eliminating rapid ultrasonic firing (EERUF) [3]; and (b) an obstacle avoidance method called the vector field histogram (VFH) [1,2]. The VFH method uses a two-dimensional Cartesian grid, called the Histogram Grid, to represent data from ultrasonic (or other) range sensors. Each cell in the Histogram Grid holds a certainty value that represents the confidence of the algorithm in the existence of an obstacle at that location. This representation was derived from the certainty grid concept that was originally developed by Moravec and Elfes in [5]. Based on data in the Histogram Grid, the VFH method creates an intermediate data representation called the Polar Histogram. The spatial representation in the Polar Histogram can be visualized as a mountainous panorama around the robot, where the height and size of the peaks represent the proximity of obstacles, and the valleys represent possible travel directions. The VFH algorithm steers the robot in the direction of one of the valleys, based on the direction of the target location. Using VFH, CARMEL avoided obstacles while moving at speeds of up to 780 mm/sec.

Objects recognition was facilitated by tagging each pole with an omni-directional barcode. The object tag design used for CARMEL consists of a black and white stripe pattern placed upon PVC tubing with a four inch diameter, allowing the tags to be slipped over the object poles. The vision algorithm for extracting objects from an image required no preprocessing of the image. The algorithm makes a single pass over the image, going down each column of the image looking for a white-to-black transition that would mark the start of a potential object. A finite state machine keeps track of the number and spacing of the bands. After finding enough bands to comprise a tag the algorithm stores the tag id and pixel length. Once a column is complete, the eligible objects are heuristically merged with objects found in previous columns. The algorithm has an effective range of about 19 meters.

CARMEL successfully integrated high-speed obstacle avoidance with long-range vision to win the AAAI Robot competition. CARMEL placed third in stage 1 and first in stages 2 and 3. In the second stage, CARMEL found and visited all ten objects in under ten minutes; no other robot could find and visit all ten objects in under the allotted 20 minutes for stage 2. In stage 3, CARMEL finished first by visiting the three objects and returning to the start position in just under three minutes. For more details on CARMEL see [4].

References

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