Cooperating Robots
Lecture Notes
Features

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This note considers one of the items in the lecture plan.

Sensors. Infrared sensors, Cameras. Image processing. Operations. Feature extraction. Reduction to 1D.

Feature Detection

The recommendation is to manipulate the environment to create optimal conditions for detection of features. I shall proceed under the assumption that the environment is 1-dimensional in the sense that we aim at detecting vertical edges, either texture edges, which are painted on a surface, or boundary edges, which delineate the boundary of an object. This choise of features is described by Hafner [1]. If an infrared distance sensor is pointed to the left and to the right of a texture edge, there will be little difference in the readings. If the same experiment is conducted with a boundary edge, the difference between the two readings will be large. This means that an edge can be classified as either a texture edge or a boundary edge by means of the signal from an infrared sensor.

A vertical edge can be detected from an image by summing for each column all pixels in that column. This gives us a 1-dimensional signal which has the shape of a (noisy) step edge.

If the noise is not very pronounced, one can apply a threshold to detect the edge. There are difficulties, however. There may be noise in that the signal fluctuates locally. Also there may be a systematic trend such that for instance the image generally is brighter on one side that in the other.

Small local fluctuations can be removed by smoothing the signal. The simplest method is to compute the average of two neighbor pixels. Repeated application for a few iterations approximates smoothing by a gaussian filter. The problem of uneven illumination level (one side bright, the other dark) can be solved by diffentiation of the signal. Differentiation also accentuates edges. If there is a steep edge, the differential quotient will be large. Thus a way to look for edges is to apply first a smoothing filter, and then to differentiate the resulting curve. This is usually done by filtering with the derived gaussian filter. This follows from the equations

$$\frac{\partial}{\partial x}(L * N) = L * \frac{\partial}{\partial x}N$$

($*$ means convolution or filtering)

On this curve one then has to locate maxima(dark/bright changes) and minima(bright/dark changes).

One should attempt to make all detections as zero-crossings, that is construct a signal such that changes of sign marks the wanted features. For edge detection this means differentiating the gaussian once more to obtain zero crossings at the edge locations.

Another way to think of feature (edge) detection is to match a profile of the feature (edge) that we want to detect with the signal at each point along the signal. the score of the match is computed as pointwise multiplication and summation of the feature and the signal (their scalar product). We will expect that the scalar product will be maximum at the position of the edge. The result will give us a curve with a maximum at the location of the edge. Thus we must search for a maximum as described above. The difficulty with this method is that it is not robust with respect to uneven illumination.

The filter cannot be applied at the boundary. One can use several solutions:

Periodic repetition of signal

Taper of signal to zero at boundary by multiplication with window

Mirror signal at boundary

Normalized convolution. Filter coefficients are discarded if signal is not defined. Remaining coefficients normalized.

Motion Detection

Motion detection is made simply by subtracting signals for two different points in time. A moving step edge becomes a hump with a rising and a falling edge in the subtracted signal. The edges are found as described above. The width of the hump is the motion *velocity*. Direction of motion can be determined by comparison with one of the original signals. This is necessary since it is not possible to distinguish a black/white transition moving to the right from a white/black transition moving to the left based only upon only the difference signal.

Litteratur

[1] Verena Hafner. Learning places in newly explored environments. In Meyer, Berthoz, Floreano, Roitblat, and Wilson, editors, *SAB2000 Proceedings Supplement Book*. International Society for Adaptive Behavior, 2000. postscript at http://www.ifi.unizh.ch/groups/ailab/publications/2000.html.