TECHNISCHE UNIVERSITÄT DRESDEN

Fakultät Elektrotechnik und Informationstechnik • Institut für Automatisierungstechnik

Hierarchical segmentation and topological interpretation based on optical flow

Motivation

In recent decades, one of very important problems in computer vision is to reconstruct scenes of surrounding environments from 3D motion based on optical flow (OF) extracted from sequence of images.
Bio-mimetic OF navigation solutions use often some global or regionally averaged OF field information such as balancing of the image flow for flight in a corridor or evaluating the maximal flow for nearest obstacle detection, smoothed centering between averaged object distances or OF divergence processing for obstacle avoidance. However, these mentioned solutions are based on more or less *classical quantitative* decision making implementations.

Problem definition

The optical flow-based system shown in Fig. 1 uses a *mono-camera* (Cam) as main navigation sensor to support imaging information to the OF processor of autonomous mobile robots.

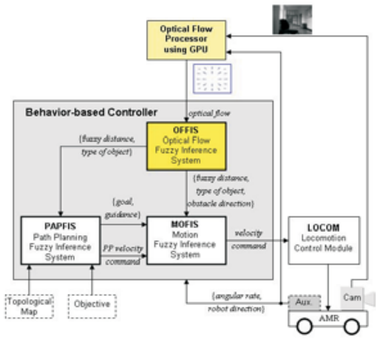

Figure 1. General diagram of optical flow-based navigation system

The OF processor extracts optical flow vectors from pairs of images. The OF vectors contain information about the environment necessary for mobile robot navigation.
Perception of the control system is realized by the OF fuzzy inference system (OFFIS) by an approach of hierarchical segmentation which partitions the OF vectors into quadrants in order to process regionally averaged optical flow patterns.
The OFFIS module supports the path planning fuzzy inference system (PAPFIS) and the motion control fuzzy inference system (MOFIS) with information about type of indoor objects such as walls, corners, doors and corridors, direction of obstacles, and fuzzy distances to observed objects.

Hierarchical segmentation

Based on the hierarchical segmentation described in [1], the optical flow is classified into quadrants.
Qualitative optical flow classification is related quite intuitively with some averaged metrics over certain flow field regions. Averaging of optical flow patterns enables the perception to reduce stochastic errors in optical flow determination and provides smoothing for 3D artifacts in the image flow.
Fig. 2 illustrates the hierarchical segmentation with two layers. The layer 1 represents the four basic optical flow field quadrants (Q_1, Q_2, Q_3 and Q_4) shown in Fig. 2a. If more details in any quadrant Q_n of layer 1 (n=[1... 4]) are under consideration, this optical flow quadrant can be decomposed further in layer 2 with quadrants Q_{n1}, Q_{n2}, Q_{n3} and Q_{n4}. Fig. 2b sketches an example of the hierarchical segmentation in layer 2 for quadrant Q_4 which contains an obstacle.
By the same way it is possible to zoom in deeper layers. It is evident that this zooming-in feature delivers more detailed structural insight at the cost of increased computational effort.

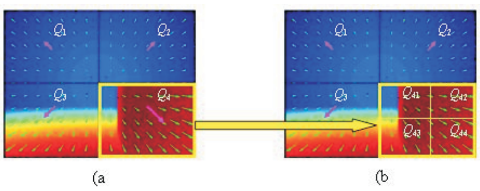

Figure 2. Hierarchical segmentation of optical flow field
a) quadrants in layer 1, b) quadrants in layer 2

Two-plane built indoor objects

It is noticeable to identify that walls, corners, doors and corridors, which are the typical indoor objects (TIOs), have relatively stable shapes. The 2D images in Fig. 3a indicate that the TIOs are able to be depicted by two planes, so they are possibly called two-plane built indoor objects (TPOs).
Fig. 3b illustrates an approach of topological interpretation based on optical flow through hierarchical segmentation. This approach estimates the image-contained planes and tilts of them to distinguish the TPOs from each other.

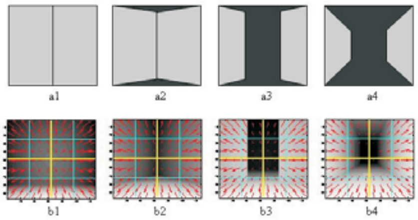

Figure 3. Two-plane built indoor objects
3a) Two-plane built shapes of walls (1), corners (2), doors (3), and corridors (4)
3b) Optical flow images of walls (1), corners (2), doors (3), and corridors (4)

Topological interpretation

Based on the results of hierarchical segmentation and averaged optical flow metrics of quadrants, a topological interpretation is performed to obtain more structural details from the surrounding environment.
Be different to classical approaches, the topological interpretation is based mainly on qualitative information rather than usually quantitative one.
By comparing the averaged metrics among quadrants, it is possible to identify planes and TPO interpretations by the way illustrated in Fig. 4.

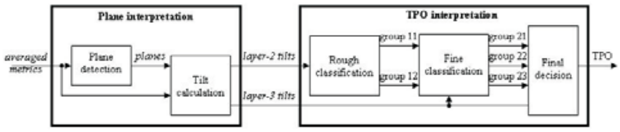

Figure 4. Topological interpretation based on averaged metrics of optical flow

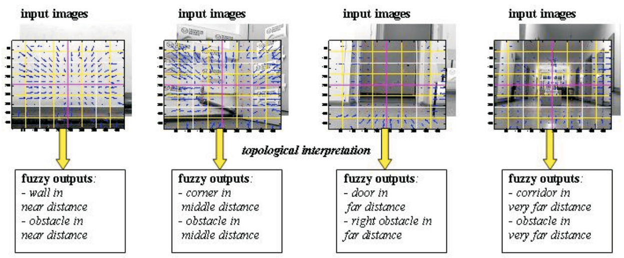

Figure 5. Typical results of topological interpretation

Experiment results

To evaluate the hierarchical segmentation and topological interpretation algorithms under most realistic conditions, several experiments has been performed in a real office environment by an autonomous mobile robot IfAbot with a camera Logitech C310 HD 1280x720 pixels as a main sensor.
Fig. 5 illustrates some interpretation results of typical situations in the experiments. The experiment results proved that the topological interpretation algorithms are reasonably robust against noise, and useful for visual navigation including motion control and path planning in indoor environments.

References

[1] N. A. Mai and K. Janschek, "*Bio-inspired Optical Flow Interpretation with Fuzzy Logic for Behavior-Based Robot Control*," In: Proc. of the RAAD 2009 18th International Workshop on Robotics in Alpe-Adria-Danube Region, Brasov, Romania, pp. 68-77, May 25-27, 2009.

Kontakt

Technische Universität Dresden
Fakultät Elektrotechnik und Informationstechnik
Lehrstuhl für Automatisierungstechnik
Prof. Dr.techn. Klaus Janschek
01062 Dresden
www.et.tu-dresden.de/ifa

Ansprechpartner: **M.Sc. Ngoc Anh Mai**
Telefon: +49 351 463 35391
Telefax: +49 351 463 37039
E-Mail: ngoc_anh.mai2@mailbox.tu-dresden.de
Besuchsadresse: Barkhausen-Bau, Georg-Schumann-Str. 11, Zi. S 84