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Introduction

1.1 What to do

Due to the fact that many types of sensors can be used to help a mobile robot find its way through known or even unknown environments, analyzing and combining of these inputs is expensive in work and money. For the cause that visual sensors become more and more affordable and sophisticated and most active sensors (e.g. laser scanners, infrared detectors and ultrasonic transducers) are not used by human perception, it should be possible and effective to restrict to pure vision systems. In particular, omnidirectional vision systems offer supplementary advantages by achieving complete 360 azimuthal degree views of the environment. Most of them are combinations of digital cameras and mirrors, which can be shaped (e.g. conic,spherical, hyperbolic) and combined in different ways [4, 14, 21] (see also section 2.1).

Most interesting tasks for autonomous mobile robots are:

- **Range estimation:**

  Most types of active range sensors like ultrasonic transducers or laser scanners are expensive and limited in their ranging. Vision systems can determine range information by robust tracking of special image points or features of the environment. Therefore, it needs at least two images taken at different positions, where these points can be matched. Range can then be calculated by geometric triangulation.

- **Egomotion:**

  Determination of the moved distance, inverse to range estimation. Internal odometric sensors work well on short, but fail on long distances, where the error will accumulate. Therefore, it is useful to recalibrate them, for example by vision sensors. The idea is to identify objects and estimate their distance to the robot by using model-based knowledge.

- **Situation recognition:**

  Interpretation of the local environment depending on the situation. For further tasks, in particular for higher level tasks, it is important to analyze the situation. This is not only including range estimation to avoid collisions, but also the ability to describe the situation by identifying objects (e.g. doors, lights, persons) or circumstances (e.g. light influence).

- **Localisation:**

  The position of the robot in the workspace should be determined as exactly as possible by only using an image of the actual environment. For this task, the robot has to be trained to get an overview of „his world“, in which it will move around and work.

- **Navigation:**

  Navigation describes the complete robot application, including all those mentioned above. By combining these abilities, the robot should accept tasks and autonomously fulfill them.

1.2 How to do

The success of all of these applications only using visual sensor input strongly depends on robust image feature extraction regarding one or even multiple images. In relation to the respective task, many natural features like

- **edge or corner detection** [7, 24, 26],
- **colour information** [22, 19],
- **image deformation** [3],
- **motion detection** [29],
- **optical flow**,
- **attentional windows**

and methods to extract features from complete image data using

- **Eigenimages** [15, 23], e.g. by Principal Component Analysis (PCA), or
- **Output Relevant Features** [28]

have been discussed (see also section 2.3). Artificial features like landmarks (e.g. „beacons“) offer robust solutions, but are limited to structured industrial environment.

The ultimative goal is to make mobile robot navigation (including all sub-applications) possible in all kinds of environments, by only using omnidirectional vision, without any artificial landmarks and without a big effort in recalibration, reprogramming or training time.

1.3 Here to do

In this thesis, experiments are made in an office environment with a catadioptric system using a hyperbolic mirror and a standard digital video camera. Experiments have been mainly made under constant environmental conditions, which means constant light influence, no active motion (like persons running around) or passive motion (like door opening and closing between two pictures).

Besides range estimation, situation recognition and egomotion using symmetry as a natural feature, localisation using Output Relevant Features (ORFs) is discussed. Symmetry has been successfully used in different computer vision tasks [5, 16, 27, 10], but not in connexion with omnidirectional vision for mobile robot applications (as known).

This work includes the following chapters:

- **Chapter 2: State of the Art**

  Actual work in research areas related to this work are referenced. These are first belonging to omnidirectional vision itself, different types of mirror shapes and mirror combinations. Further on, applications in mobile robotics and applied methods to extract natural features using omnidirectional systems are discussed. Additionally, experiments regarding symmetry in computer vision are mentioned.

- **Chapter 3: System Setup**

  Robot configuration, omnidirectional vision system and environment used for all experiments will be briefly explained.

- **Chapter 4: Hyperbolic Mirror**

  Properties of the hyperbolic mirror are mathematically proven. Additionally, applications and results using the determined formulas are presented, e.g. correct camera-mirror calibration and bird’s eye view.

- **Chapter 5: Symmetry as a Natural Feature**

  After an introduction to symmetry, including motivation and definition, own symmetry approaches and algorithms are shown. Different symmetry image calculation methods are discussed and explained using a concrete example of a usual office picture.

- **Chapter 6: Experiments using Panoramic Images**

  This chapter describes outcarried experiments using symmetry as a feature in omnidirectional context. Results in range estimation, situation recognition by object classification and ideas for egomotion estimation will be presented.

- **Chapter 7: Localisation using Output Relevant Features (ORFs)**

  Localisation experiments with the Output Relevant Features method are discussed. Any ORF struct, equal to a single-layer feed-forward perceptron network based on the Hebbian learning rules, is trained to estimate a given output value. Tests are made for 1-dimensional and 2-dimensional position inter- and extrapolation.

- **Chapter 8: Conclusions**

  Applications, experiments and results of the previous chapters are summarized refering to their performance and efficiency. Possible improvements and further approaches belonging to symmetry in panoramic and mobile robot context are mentioned.