



Introduction

A mobile robot that was initially developed for sample management in a bioreactors [1].



Figure 1: The mobile robot consists of a robot arm placed on a battery-driven, wheeled platform. Perception is realized via on-board laser rangefinders and wheel encoders at the base as well as a force/torque sensor and a high resolution camera mounted on the robot's tool.



Figure 2: Novel algorithms based on the high resolution images from the camera enable the robot to discover an unknown laboratory and to monitor Fermentor stations.

Bioreactor Monitoring in a Cell Culture Development Laboratory with an Autonomous Mobile Manipulator

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Figure 3: Automated mapping and path planning in an unknown laboratory.



Figure 4: Detection and localization of people and laboratory equipment.

Visual tracking, that is integrating fast computer vision and image understanding techniques with sequential estimation methodologies (tracking), for the purpose of localizing one or more moving objects in a video sequence. More or less detailed models can be used for this task, and an efficient integration of all available information greatly enhances the quality of the estimation re-

With such a target in mind, OpenTL (Open Tracking Library) was developed. A general-purpose library for markerless tracking, that provides a user-friendly high-level application programming interface (API) for a variety of applications, like robotics, surveillance, surgery or navigation, etc. [2]

Method

Map acquisition is implemented based on the distance information of the laser rangefinders located at the front and rear side of the mobile robot. Each scan at a given position determined by the wheel encoders reinforces the confidence with which map cells can be declared as occupied (by an obstacle or wall) or empty, in which case the robot can move there. The left image shows an automatically acquired map with an overlayed floor plan, which matches very closely the generated map. The right image depicts how the path planning algorithm computes a collision-free, shortest distance path base on an occupancy grid / map.

We accomplished automated mapping and path planning in the changeable lab as well as first walkthroughs. Progress in image processing will allow automated monitoring and error detection on fermentor stations.





The object detectors and trackers are implemented based on particle filters. Each particle represents a hypothetical pose of a known object. Several hundred hypotheses are evaluated at each image processing step for every tracked target resulting in an approximate estimation for the searched object. In the pictures on the left, the hypotheses of each particle filter are indicated by white rects, the most probable position of the tracked target is indicated by green

In the shown pictures, the scientist's face and hand (upper row) are detected and tracked by the robot until he arrives at a fermentor station (lower row) where the fermentor is detected as well. This way and in combination with the automated mapping and path planning (see Figure 3) a human guide can teach a lab walkthrough and indicate positions of interest for a repetitive fermentor monitoring routine, without preprogramming any knowledge about the environment.



References

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Goal

The goal is for the robot to provide 24/7 surveillance of high cell density perfusion bioreactors that typically operate for 3 – 6 months, thereby reducing the burden on human monitoring of these systems.



Figure 5: The Application Domain - a changeable Biotech Laboratory.

Figure 6: The robot checking a fermentor station.

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