A Mobile Service Robot for Life Science Laboratories

Erik Schulenburg, Norbert Elkmann, Markus Fritzsche, and Christian Teutsch

Fraunhofer Institute for Factory Operation and Automation, Sandtorstrasse 22,
39106 Magdeburg, Germany,
`<firstname>.<lastname>@iff.fraunhofer.de`

Abstract. In this paper we presents a project that is developing a mobile service robot to assist users in biological and pharmaceutical laboratories by executing routine jobs such as filling and transporting microplates. A preliminary overview of the design of the mobile platform with a robotic arm is provided. Safety aspects are one focus of the project since the robot and humans will share a common environment. Hence, several safety sensors such as laser scanners, thermographic components and artificial skin are employed. These are described along with the approaches to object recognition.

Key words: service robotics, safety, object recognition

1 Motivation

Biological and pharmaceutical research entails a great deal of repetitive manual work, e.g. when preparing experiments or loading equipment such as drying chambers and centrifuges. Classical automation interconnects such units with band conveyors or indexing tables. The basic idea behind the Life Science Assistant (LiSA) is to interconnect equipment with a mobile service robot, thus making automated experiment cycles flexible, while allowing stations to be used simultaneously for other purposes. In addition, the robot will help lab technicians prepare experiments, e.g. by collaboratively executing transportation tasks or filling microplates. The LiSA project is constructing a demonstrator that executes the aforementioned tasks.

Safety aspects, only treated marginally in similar projects [1], are one focus of the project. Since robots and humans share a common environment, safety is an important issue in service robotics. It assumes even greater importance in the life sciences because a robot may handle toxic or hazardous substances.

Figure 1 presents a design study of the particular robot currently under development. The development work will converge in the construction and testing of the final service robot by March 2009.

2 Project Overview

Development of the LiSA robot incorporates different objectives. First of all, a mobile platform with a custom-build robotic arm has been designed (see Fig-

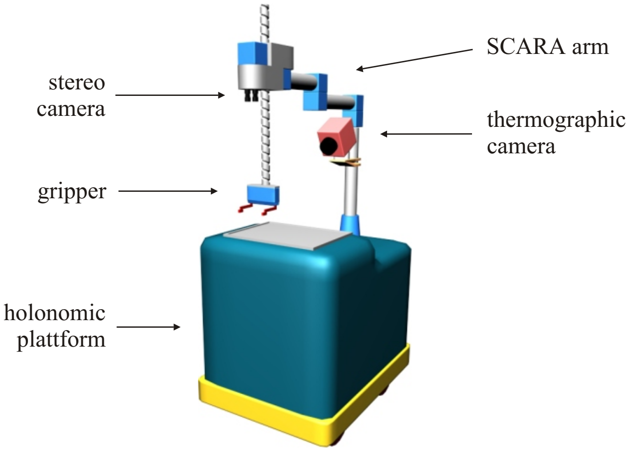


Fig. 1. LiSA platform design study.

ure 1). The platform is equipped with a holonomic drive to provide the high maneuverability needed to navigate in a cramped laboratory environment. Two SICK s300 laser scanners are mounted at opposite corners of the platform. The scanners' 270° field of view generates a 360° field of permanent 2-D view. This is used together with a gyroscope and wheel encoders for Markov localization in an a-priori map.

Since the robotic arm basically performs pick-and-place operations, a classical SCARA design with a two-finger gripper was selected. The robotic arm is able to operate to the left or right of the mobile platform. It is equipped with a stereo camera system for object recognition and camera-guided movement, the approaches to which are described in section 4. Additionally, a combined camera devices delivers images in the visible as well as the infrared spectrum. It is mounted on a rotating stage at the base of the robotic arm and moves in concert with the arm. This camera is utilized to roughly localize objects and to detect human interaction in front of the gripper. This is just one of many components that assure interaction with the LiSA service robot is safe. Further safety aspects are described in section 3.

Intuitive multimodal interaction is another objective of the LiSA project. To this end, a commercial dialog engine is employed, which supports mixed-initiative, natural language dialogs and conversation in full sentences. It has been upgraded for simultaneous input through a touch-sensitive graphical user interface. This permits combining touchpad input and speech signals in a single statement, e.g. by combining the sentence “Take the sample from this point to that point” with two touchpad input events on the map of the laboratory.

3 Safety

Since robots and humans share a common environment and actually cooperate, safety is an important aspect of service robotics. Current standards, e.g. EN ISO 13849 (Safety of machinery), primarily target the industrial sector and are inappropriate for mobile robot assistants. A first approach to provide general principles for the design of human-machine interaction systems has been done with . The ensuring basic requirements are:

- Maximum speed of tool center point (TCP) of 250 mm/s,
- Maximum effective force of 150 N,
- Reduced power of 80 W,
- Survey of the TCP position, ensuring safe distance to humans and
- Immediate stop if humans enter the robot's workspace.

Approaches to safety conformable design of robot assistants include passively compliant systems and actively monitoring sensors [2].

The LiSA project has employed several safeguards to protect humans and the environment. Along with the safety scanners (SICK s300) and classical bumpers around its bottom edges, the platform is equipped with four additional laser scanners (Hokuyo URG-04LX). These scanners are mounted at the bottom of each of the robots' sides and angled upward, creating a protective utilzed for 3-D obstacle avoidance. A violation of a scanner's protective field will cause the platform to slow down or stop immediatety.

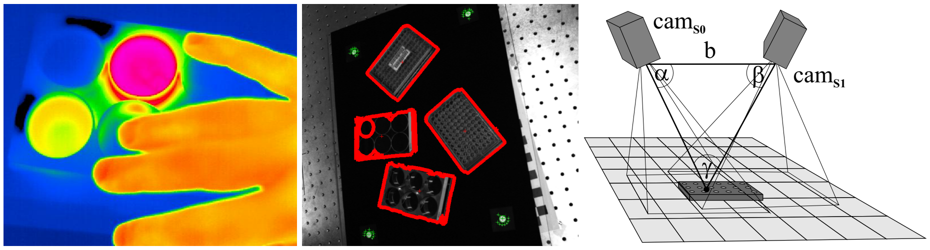
The slow moving robotic arm is also equipped with multiple safety features. Torque measurement and contouring error control are integrated in the joints for collision detection and the manipulator is covered by a pressure-sensitive artificial skin that also provides information on the location of a collision. The manipulator itself is padded to prevent injuries.

The gripper ist additionally monitored by a thermographic camera to detect humans through their body heat. Figure 2(a) presents a sample image from the thermographic camera.

4 Object Recognition

Optical sensors identify and recognize the exchange positions and the microplates. To reliably position the gripper vis-à-vis objects being picked up, two digital cameras sample the immediate environment. Their lenses enable capturing an area of about 400×300 mm. By using subpixel interpolations, a resolution of ca. 9 pixels/mm^2 is produced, which is sufficient to determine the necessary positions with the accuracy required.

The detection of the microplates at the exchange positions is based on a fast and adaptive segmentation approach. In the first step, a histogram is computed. As proposed by Rosin [3], the histogram value at the half between the minimum and the maximum is taken as the binarization threshold. The segmented result represents the area of the microplates. In subsequent steps, the border is calculated in an 8-neighborhood. The rotating calipers method is used to obtain the smallest bounding rectangle from the extracted contour. This rectangle's orientation defines the orientation of the microplate's orientation (see Figure 2(b)).



(a) (b) (c)

Fig. 2. Components of LiSA's optical system. A thermographic component for detecting human interaction (a), a camera component for 2-D position tracking (b) and a stereoscopic sensor for 3-D sampling (c).

The determination of exact 3-D position and orientation is based on a photogrammetric approach and uses both digital cameras. Their positions and orientations are predetermined in a prior calibration step [4]. The triangulation principle serves as the basis for calculating the relative 3-D coordinates of objects visible to both cameras (see Figure 2(c)). Corresponding pixel pairs are identified by a statistical correlation between image segments on the epipolar lines [5]. The small base distance b of 150 mm necessitates aligning the camera's perspective to attain sufficiently high precision (< 0.5 mm) in the stereo-vision approach based on triangulation. When the robotic arm moves, the algorithms not only track the 2-D position of microplates but also take 3-D samples of an object's surface. The resultant height data supports algorithms that detect plates on top of one another.

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