LiSA: A Robot Assistant for Life Sciences

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Abstract. This paper 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. Moreover, the approaches to localization and intuitive multimodal human-machine interaction using speech and touchpad input are described. One focus of the project is aspects of safety since the robot and humans will share a common environment.

Key words: service robotics, mobile robot, human-machine interaction

1 Introduction

Biological and pharmaceutical research entails a great deal of repetitive manual work, e.g. preparing experiments or loading equipment such as drying chambers and centrifuges. Classical automation uses band conveyors or indexing tables to interconnect such units. The basic idea behind the Life Science Assistant (LiSA) is to employ a mobile service robot to interconnect equipment. This makes automated experiment cycles flexible, while simultaneously allowing stations to be used for other purposes. In addition, the robot helps employees 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 is an important aspect in service robotics since robots and humans share a common environment. Previous projects [1, 2] only marginally examined relevant requirements. Safety assumes even greater importance in the life sciences because a robot may handle toxic or hazardous substances. The LiSA project reflects this in its manifold safety sensors.

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.

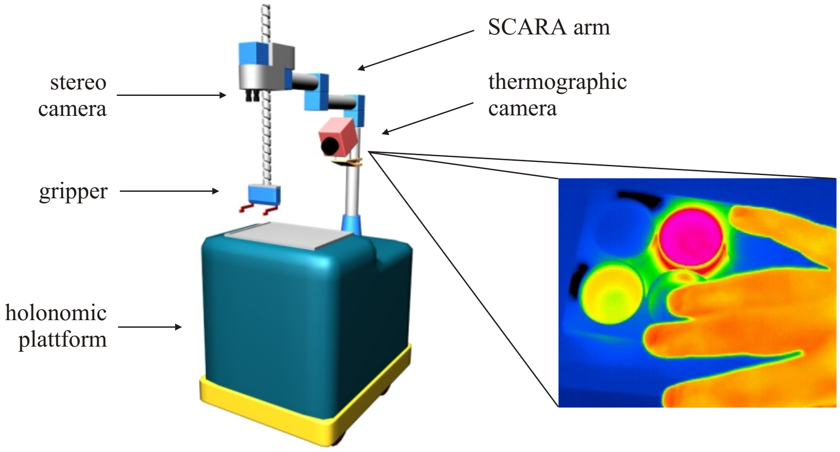

Fig. 1. LiSA platform design study (left) and thermographic image (right).

2 Hardware and Safety Components

The robot assistant's design consists of a custom-built robotic arm mounted on a mobile platform as depicted in Figure 1.

The mobile platform is equipped with a holonomic drive. For navigation and obstacle avoidance it is equipped with a gyroscope, wheel encoders and six 2-D laser scanners. The laser scanners provide an alert area and a protection area. If an obstacle violates the alert field of a laser scanner, the mobile platform slows down. Activating the protection area or one of the bumpers mounted all around the bottom edges of the platform results in an immediate stop.

The robotic arm is covered by a pressure-sensitive artificial skin for collision detection. The SCARA design selected gives the manipulator clearly defined directions of movement (horizontal for the joints, horizontal and vertical for the linear axis). Therefore, tactile sensor elements only have to cover specific areas. Torque measurement and contouring error control are integrated in the joints as additional electronic safety functions. Moreover, the manipulator is padded to prevent injuries in the case of a collision.

The robotic arm is equipped with two camera systems for camera-guided movement. A stereo camera system is installed near the linear axis and a combined camera system is mounted at the base of the robot arm. The stereo camera determines the 3-D pose of exchange positions and the microplates with high precision ($< 0.5\,\mathrm{mm}$) based on a photogrammetric approach. Corresponding pixel pairs in both cameras are identified by using statistical correlation between image segments on the epipolar lines [3]. This information is used to guide the robotic arm. The combined camera device consists of two calibrated cameras, one for the infrared and one for the visible spectrum. The thermographic component detects human interaction in front of the robotic arm and its gripper to ensure the safety of the manipulation process (see Figure 1 (right)).

3 Localization and Navigation

For localization the LiSA robot employs a novel sensor configuration that increases safety by enabling it to navigate with full 3-D obstacle avoidance, produced by combining 6 laser scanners to a robot centered 360° 3-D laser scanner as depicted in Figure 2 (left). Two laser scanners (SICK s300) are mounted on opposite corners of the robot. The scanners' 270° field of view generate a 360° field of permanent 2-D view with overlapping regions. This combined 360° scanner is used for localization in an a-priori map and to avoid collisions with humans. It is inadequate for general obstacle avoidance, since obstacles may interfere with the robot in its complete bounding box. Thus, the setup is extended by four Hokuyo URG-04LX laser scanners, each of which is mounted at the bottom of one of the robot's sides and angled upward, enabling the robot to detect obstacles in the respective data. If this occurs, the 3-D laser data points (belonging to the obstacle) are projected onto the floor plane and inserted into a local perception map. Thus, the robot generates a detailed perception map while moving (see Figure 2 (right)). For obstacle avoidance, the horizontal localization scanners are combined with the perception map regarding the current robot position.

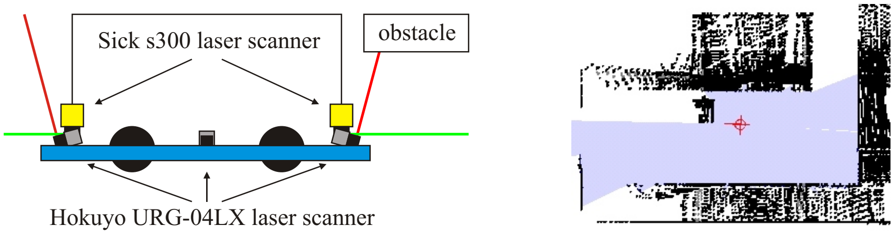

Fig. 2. Laser configuration of the LISA robot (left) and combined sensor data (right).

The complete system has been tested in the robot simulation environment USARSim [4]. The simulation environment is connected to the hardware abstraction layer of Player/Stage [5]. Figure 2 (right) shows the standard player sensor data visualization tool as well as the combined sensor data (blue) and the map generated by the Hokuyo scanners (black). The robot is aware of its entire environment including tabletops. A classical horizontal sensor configuration would only be able to detect the chair and table legs.

4 Multimodal Interaction

Interaction with LiSA is multimodal, i.e. spoken and touchpad input is possible. Speech recognition is speaker-independent. The commercial dialog engine used for LiSA supports mixed-initiative, natural language dialogs and conversation in full sentences. It has been expanded for multimodal input based on experiences from various projects [6, 7].

The dialog engine extracts all pieces of information from a spoken utterance and touchpad input and enters them into a predefined XML form, requesting missing pieces of information and forwarding a completed form to the LiSA Task Manager. Spoken commands and touchpad input can be used in combination or independently throughout the dialog. This includes combinations of touchpad input and speech signals in a single utterance, e.g. the sentence “take the sample from this point to that point” is combined with two touchpad input events on the map displayed. The dialog engine interacts with a knowledge database that stores information on the location of laboratory inventory such as the fluorescence reader or drying chambers and their location in the different rooms of the lab. All these features generate intuitive mixed-initiative, multimodal interaction between laboratory assistants and LiSA.

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References

1. Prassler, E., Dillmann, R., Fröhlich, C., Grunwald, G., Hägele, M., Lawitzky, G., Lay, K., Stopp, A., von Seelen, W.: Morpha: Communication and interaction with intelligent, anthropomorphic robot assistants. In: Proceedings of the International Status Conference – Lead Projects Human-Computer-Interactions, Saarbrcken (Germany) (2001)
2. Scherer, T., Poggendorf, I., Schneider, A., Westhoff, D., Zhang, J., Lutkemeyer, D., Lehmann, J., A.Knoll: A service robot for automating the sample management in biotechnological cell cultivations. In: Emerging Technologies and Factory Automation. Proceedings. ETFA ’03. IEEE Conference. Volume 2. (2003) 383–390
3. Shi, J., Tomasi, C.: Good features to track. In: Proc. Computer Vision and Pattern Recognition (CVPR’94). (1994) 593–600
4. Albrecht, S., Hertzberg, J., Lingemann, K., Nüchter, A., Sprickerhof, J., Stiene, S.: Device level simulation of kurt3d rescue robots. In: Third Intl. Workshop on Synthetic Simulation and Robotics to Mitigate Earthquake Disaster (SRMED 2006). CDROM Proceedings. (2006)
5. Gerkey, B., Vaughan, R., Howard, A.: The player/stage project: Tools for multi-robot and distributed sensor systems. In: Proceedings of the International Conference on Advanced Robotics (ICAR 2003), Coimbra, Portugal, June 30 - July 3, 2003. (2003) 317–323
6. Sonntag, D., Engel, R., Herzog, G., Pfalzgraf, A., Pfleger, N., Romanelli, M., Reithinger, N.: Smart web handheld – multimodal interaction with ontological knowledge bases and semantic web services. In: Proc. International Workshop on AI for Human Computing (in conjunction with IJCAI), Hyderabad, India. (2007)
7. Horndasch, A., Rapp, H., Röttger, H.: SmartKom-Public. In: SmartKom: Foundations of Multimodal Dialogue Systems. Springer, Berlin (2006)