EXPERIENCES AND FUTURE DEVELOPMENTS

Insights from AutoPnP

Research results from AutoPnP indicate the technical readiness for office cleaning robots but also identify the deficits of the current prototype, which are majorly its price tag, clumsiness, and working speed. Necessary advancements for a market-ready cleaning robot include:

- Building a more compact robot with higher agility
- Integrating all tools on-board (omitting tool changes)
- Optimized sensor placement for more efficient dirt detection, cleaning verification, and collision checking
- Using a simpler arm kinematic (faster handling, price)
- Utilizing local 3d mapping for safer yet faster operation

Future Developments

In a next step Fraunhofer IPA will team up with cleaning machine manufacturers, mobile service robot manufacturers, and manipulator developers in order to develop an economically viable, versatile, and modular platform for the professional cleaning business. The project targets the tasks of floor cleaning and waste disposal, however, in a much more time and cost-efficient manner. The robotic platform will provide basic robotic functions (e.g. sensing, navigation, manipulation, batteries, computers) and will be capable of tasks like vacuum cleaning and waste disposal or wet cleaning. The modularity of the already existing software components will facilitate their transfer to a new machine.

PUBLICATIONS


CONTACT

Fraunhofer Institute for Manufacturing Engineering and Automation IPA
Nobelstrasse 12
70569 Stuttgart
Germany

Dipl.-Ing. Richard Bormann M. Sc.
Telephone +49 711 970-1062
richard.bormann@ipa.fraunhofer.de

MOTIVATION

Today, the professional cleaning sector is confronted with a set of challenges to their business:

- Demographic change causes shortage of qualified young professionals
- Customers ask for increased cleaning performance (higher performance attained by using cleaning machines)
- Manually operated cleaning machines require (unproductive) training periods for employees
- High fluctuation in cleaning staff generates further need for training periods
- Cleaning should happen preferably during the night hours, a time at which workers claim higher wages
- Cleaning sensitive areas (cleanrooms in industry and pharmacy, confidential areas, security zones) necessitates very trustworthy personnel

VISION

A solution to these challenges is to schedule available professionals for demanding tasks such as desk or sanitary cleaning while relieving them from simpler, yet time consuming activities which are transferred to an autonomous robotic cleaning assistant. Two of such tasks are floor cleaning and waste disposal which account for 70% of the daily cleaning efforts.

A current trend in floor cleaning is to define a desired level of cleanliness which has to be retained by the daily cleaning efforts. In response to these demands of the professional cleaning sector Fraunhofer IPA developed the world’s first autonomous office cleaning robot prototype within the research project AutoPnP, which targets the tasks of waste bin disposal and focused floor cleaning. The application was implemented and demonstrated with Fraunhofer IPA’s multi-purpose service robot Care-O-bot³. Necessary advancements of the gripping and manipulation hardware were contributed by collaborator Schunk. The complete realization process was accompanied by the advice of Dussmann, a large German cleaning company.

DEVELOPMENTS IN AUTOPNP

The developed cleaning robot prototype is capable of dividing a given floor map of its working environment into single rooms or units, visiting them one after another, inspecting their ground floor for dirt spots, searching for waste bins and disposing them into a collection container in the robot’s tool trolley. After waste disposal, the robot can autonomously exchange its hand, which is used for handling waste bins, against a vacuum cleaner, which is stored in the trolley, and clean the found dirt spots. This focused cleaning effort avoids cleaning the complete ground floor on a daily basis while keeping it at a desired level of cleanliness. Once a group of nearby rooms has been cleaned the robot grasps its trolley and pulls it closer to the next group of rooms to clean.

Automatic Floor Plan Division

Any floor plan of the building (provided or generated by the robot), can be separated into single rooms or working units. Each unit is displayed in another color in the image on the right side.

Systematic Room Visiting and Scanning

On top of the room division, the robot puts nearby rooms into groups which are in close driving distance to a shared trolley placement location (green groups). The groups and rooms are visited in an optimal order. Inside each room, the robot inspects the ground floor systematically along a grid of points.

Dirt Detection, Dirt Mapping, and Vacuum Cleaning

While inspecting the ground floor the robot captures RGB-D data (color images and 3d geometry) which can be analyzed for the presence of ground pollutions and waste bins.

Using the 3d data the robot can separate the ground floor from the remaining structures in the room (black in the upper right image). Then, the color image of the ground area is transformed into a virtual aerial perspective to remove perspective distortion. A spectral analysis is applied in the following to separate regular ground floor patterns from outstanding patterns of pollutions (green circles). All detected pollutions can be stored in the robot’s map (lower right image) for cleaning them later with a vacuum cleaner.

Waste Disposal

Waste bins are detected in the RGB-D data by means of object detection or marker tag detection. The robot grasps detected waste bins, clears them into the trolley, and brings them back.

Tool Change

The robot hand can easily be exchanged with a vacuum cleaner using a tool changing system. For the exchange the tool changer is aligned very precisely via visual servoing.