Machine Vision 361.012

Navigation based on Camera

Homework Part I

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May 3, 2023

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1 Motivation

There is a continuing growth of technologies in indoor navigation: human assistance, tourist guidance, AR.[3]
Also, human-centered robots have become an important research field due to their ability to assist and support humans, i.e., in hospitals, restaurants, and service areas. [1]

Another motivation lies in the safety (Integrity) aspect that comes with navigation of unmanned vehicles:
This ranges from Autonomous Driving nowadays to potential for urban air mobility in the near future. [2] Integrity is the measure of the trust that can be placed in the correctness of the information supplied by a navigation system. Integrity includes the ability of the system to provide timely warnings to users when the system should not be used for navigation. But in many circumstances, this is not yet given and cannot be guaranteed. [6]

GNSS-denied environment make the use of alternative methods necessary.
LIDAR or RADAR is expensive, if it has to be small enough to be mounted on robots, hence why low cost methods are needed.
Additionally, many use cases on mobile robots limit the amout of available power, and thus, low power consumption of visual navigation methods are to be desired.
In many cases, visual cameras are already present due to requirements from other tasks such as monitoring and detection [6]

2 Challenge

In Urban Areas for Autonomous Driving and Urban Air Mobility, there is strong shadowing or multi-path-signals due to buildings, that influence the accuracy of the used navigation system negatively. But the Safety of the Systems has highest priority and because of the montioned reasons, GPS Positioning is not accurate enough, nor capable of reliable collision avoidance. [6]

On the obvious side, lighting conditions raise a lot of difficulties, but in indoor environments, the rooms are usually cluttered with chairs, desks and other things. This makes visual navigation, especially when there are people present, who are dynamic obstacles, hard for many robots. [4]
Moreover, many Visual Navigation Systems have been developed for motionless environments and therefore, moving objects affect the ability of the system to estimate positions. [5]

Improving Portability is another big challenge, for example good smartphone implementation, where there is a lot of movement and lower computation power.
Environment understanding would be another big step for indoor navigation. The existing methods require information about the environment, and thus, do not work in unfamiliar environments. [3]

3 Approaches

In Urban Areas, there usually is a large number of visual cues for camera-based localization algorithms.
We are experiencing an enormous development in machine learning techniques that can lead to improvements in accuracy of object detection due to larger test groups. This is essential for a good visual navigation system.

A popular approach is Visual simultaneous localisation and mapping (vSLAM): It estimates the relative pose and corresponding map simultaneously and aims to achieve global map consistency.
There are three basic types of SLAM, depending on the camera system: monocular, stereo and RGB-D, each with its own advantages and disadvantages.
For instance, RGB-D SLAM is very sensitve to Lighting conditions, but provides lots of information in the image. [5]

As for the localization, Visual Odometry (VO) is often used to locate the robot. It can be categorised infeature-based and direct methods.
Feature-based methods extract features from the images and estimate the camera pose by matching the features between the current image and the previous image.
Direct methods estimate the camera pose by minimizing the photometric error between the current image and the previous image. [6]

VO estimates the robots motion (rotation and translation) in order to localise itself (the camera sensor) within the environment. Basically, a transformation matrix between the current and the previous image is calculated. There are three standard VO motion estimation methods: 2D to 2D, 3D to 2D and 3D to 3D. Lastly, an adjustement process is performed to refine the results. This process works incremental and thus, does not aim to achive global consistency like loop detection and closing. [1]

4 Conclusion

Generally speaking, the advantages of visual navigation based on cameras are mainly the low costs, and its easy implementation in many small indoor environments. Big challenges in several fields include the Integrity of the systems as mentioned above: Visual Navigation is still prone to error and only to be used in known environments, because general environment understanding is in very early stages.
Machine Learning Techniques have advanced a lot in previous years and can help to improve the accuracy immensly - though the methods are not very effective yet.
Appart from indoor Navigation - the Navigation for Autonomous Driving and Urban Air Vehicles can be greatly improved by Visual Navigation Systems in Terms of Collision Avoidance and Integrity.

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