AR (Augmented Reality) in robotics

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Augmented Reality

What is Augmented Reality?
What is the difference to Virtual Reality?
Augmented Reality (AR)

Definition: Augmented reality is a system that enhances the real world by superimposing computer-generated information on top of it.

Augmented Reality (AR)

Augmented Reality:
- Combines real and virtual
- Interactive in real time
- Registered in 3D

Augmented Reality (AR)

Definition: Augmented reality is a medium in which digital information is overlaid on the physical world that is in both spatial and temporal registration with the physical world and that is interactive in real time.

Aland B- Craig, Understanding Augmented Reality, Elsevier 2013, p. 20
Virtual Continuum

Aland B- Craig, Understanding Augmented Reality, Elsevier 2013
Typical usage of AR
Next slide contains blood...
AR in robot development, control and interaction

Examples
Telerobotic Control Using Augmented Reality

Paul Milgram, Anu Rastogi, Julius J. Grodski*, 1995
Real Time Visualization of Robot State with Mobile Virtual Reality

Peter Amstutz and Andrew H. Fagg, 2002
Augmented Reality for Programming Industrial Robots

Using mixed reality agents as social interfaces for robots

Dragone, Mauro; Holz, Thomas; O'Hare, 2007
ARE: Augmented Reality Environment for Mobile Robots

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ARE

- Introduction
- [AR State of the Art]
- Overview
- Experiments
- Conclusion
Introduction

- Robots are more complex
- Testing in Labs
- Field tests
- AR simulates real-world problems
ARE

- ROS integration
- 3D Objects with behavior
- 2D/3D Scene of environment
- Stochastic model

Goal: Path planing
Artificial Objects

Robots, Cars, People, Pallets, other barricades

- Behavior
- Stochastic model
- Probability of existence
- Collision avoidance
Real World representation

- 2D occupancy grid map
- Octree-based 3D map
UGV - unmanned ground vehicle

Central unit:
- High-Level planer
- Path planing algorithm

Bogie

Flipper

360° Camera
Rotating Laser
IMU
GPS
Putting all together

Some snapshots of the experiment in progress, showing the augmented reality view (in ROS rviz), where is visible the 2D augmented costmap (black cells) with the inflated regions in green. The thick line in red is the path being executed by the path planner (Color figure online).

Free and A denote respectively the number of free cells of the 2D occupancy grid $M^2$ of the mapped area and the number of the cells occupied by the set $A$ of artefacts within the environment. The robot is instructed with the task to reach multiple goal locations. The path-planner computes the initial path to reach each goal and it replans a path from the robot current position to the current goal pose, whenever an artefact arrives into $M^2$, so as to find a collision-free path, if one exists. Upon the receipt of the safe path, the execution component must be able to move the robot to effectively reach the current goal. In this experiment, the overall time needed to accomplish the task is measured together with the percentage rate of the reached goal locations. Figure 7 (b) reports the performance of the robot in the navigation task with respect to different values of the space complexity of the environment (Fig. 8).

Conclusions

We propose a framework to augment the robot real world that advances the state of the art, as it introduces, together with the augmented environment, also the robot perceptual model of the augmented environment and the possibility of tuning the degree of confidence and uncertainty of the robot on what it is presented in the augmented scene. Besides being a compelling environment for robot programming, AR offers several tools for content authoring as well.

Authoring AR tools can be classified according to their characteristics of programming and content design, in low and high level, considering the concepts abstraction and interfaces complexity incorporated in the tool. Programming tools are based on basic or advanced libraries involving computer vision, registration, three-dimensional rendering, sounds, input/output and other functions. ARTToolKit, MR, MX and FLARToolKit are examples of low level programming tools. We presented the ARE framework together with a practical application of its use for robot parameter tuning. The experiments have shown how increasing complexity can affect planning and replanning abilities, and therefore that ARE is a promising experimental tool.

Experimental Results

In this section we illustrate the applicability of ARE to robot development and evaluation. The robotic platform is an UGV (see Fig. 5); two bogies on the sides are linked to a central body containing the electronics. Each bogie is made of a central track for locomotion and two active flippers on both ends to extend the climbing capabilities. A breakable passive differential system allows the rotation of the bogies around the body. Three sensors are installed on the platform; a rotating 2D laser scanner to acquire a 3D point cloud of the environment, an omni-directional camera for object detection and localization with a 360° field of view and an IMU/GPS for 3D localization.

A set of perception capabilities are embodied into the robot. The robot is provided with a real-time 2D and 3D ICP-based simultaneous localization and mapping (SLAM) system. The robot is endowed with a path planning algorithm which generates short trajectories, enabling the robot to move within the environment, preventing the collision with the dynamic obstacles. Finally a high level planner takes care of a mixed initiative control shared with the rescue operator.

We embedded the AR-based simulation framework into a ROS package. We deployed the robotic platform in a wide outdoor area, and set up two experiments, where ARE has been used to populate the real surroundings with artefacts.

In the first experiment, we wanted to check the robot ability to replan the path towards a goal location, as the frequency of the arrivals of the artefacts into the environment changes. Different parameter settings of the path-planner have also been settled, further affecting the robot behavior into the navigation task (see Fig. 6). During the experiment the path-planner component computes a new path each time the scene is updated. To measure the robot ability to replan the following time ratio is introduced

$$\rho = \frac{\rho_t}{G_t}$$
Experiments

Robot platform in a wide outdoor area. ARE used to populate this area with artifacts.

Experiment 1: Replaning path towards goal with moving objects.

Ability to replan:

\[ p = \frac{p_t}{p_t + G_t} \]

\( p_t = \text{Time needed to replan} \)
\( G_t = \text{Estimated time to reach goal} \)
Experiments

Experiment 2: Long-term capability in cluttered environment. Robot should reach multiple goal locations.

Space complexity:

\[ v = \frac{n_A}{n_{\text{free}}} \]

\( n_A \) = number of free cells of the 2D occupancy grid
\( n_{\text{free}} \) = number of the cells occupied by the set A of artifacts
Conclusion

• ARE not for low-level programming (basic functions or actions, e.g. painting gun robot)

• ARE for parameter tuning of robots

• E.g. experiments have shown how increasing complexity can affect robot abilities.

• Measuring the limits of a robot

→ ARE is a promising experimental tool
Questions?
Discussion

Can this experiment give trustworthy results?
What do you think are limits?
For which robots does it make sense, for which not?
References


Ronald T. Azuma, A survey of augmented reality in Teleoperators and Virtual Environments 6, pp-355-385

Aland B- Craig, Understanding Augmented Reality, Elsevier 2013

References

Images:
NASA
Path Planning http://www.astro.mech.tohoku.ac.jp/~ishigami/research/image/path_evaluation.jpg
Last of Us
http://www.ingame.de/files/2013/05/Vorschau-The-Last-of-Us.fw_1.png
Mercedes
http://www.wearear.de/wp-content/uploads/2013/10/Mercedes-Benz.jpg
Surgery
http://www.imedicalapps.com/wp-content/uploads/2013/08/d0bbfddd-786c-4170-91ad-28e6810a8d30_RTX12REE.jpg
Intro
Octo:
http://tommyhinks.files.wordpress.com/2012/02/voxel_digital_dublin.png
http://octomap.github.io/newcol_big.png