How to explore unknown environments with 58cm high humanoid robots?

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Introduction

Created in 2005, Aldebaran Robotics designs, develops and manufactures the humanoid robot NAO. Today more than 3000 NAOs have been sold all over the world for research and education purposes. If NAO appears to be a very efficient and appreciated development platform for these academic markets, the final objective of the company is to make humanoid robot a real companion for domestic applications. The ability of navigating in its new home will be crucial for the domestic robot. That is the reason why Aldebaran participated to the Carotte Challenge organized by ANR (the French Research Agency) and DGA (the French Department of Defense). For this challenge, five robotics teams had to explore and to map an unknown environment while recognizing and localizing detected objects.

The YOJI team

Aldebaran was involved into the Carotte challenge by leading the YOJI team gathering the vision experts of the CEA (the French Atomic Energy Commission) and Voxler (company specialized in sound processing). For the exploration, 3 NAOs were collaborating together. Originally NAO [1] is a 58cm high humanoid robot equipped with 25 joints, 4 microphones, 2 cameras, 2 ultra-sonic sensors, tactile (head and hands) and pressure sensors on the feet. Because localization and mapping based only on these sensors would have been too complicated, especially for the embedded CPU (ATOM 1,6 GHz) of NAO, we decided to add a laser range finder (Hokuyo) on the top of its head. The use of 3 NAO for the exploration was a way to compensate for the slowness of its bipedal walking (0,2m/s). A remote PC, used as a server, is connected to the three NAO with a Wi-Fi link.

Figure 1 : Two NAOs of the YOJI team

Architecture

The principle of the architecture is to have each NAO as autonomous as possible to deal with the loss of the Wi-Fi connection with the remote PC.

Each NAO is autonomously able to walk, to avoid obstacles detected by ultra-sonic and tactile sensors and by the laser and to recover from possible falls. Using the laser, NAO is able to build a map of its environment and localize itself while walking[2]. The exploration software, based on the mapping, is also embedded on each NAO. This local architecture allows each robot to explore safely its environment and to come back to its starting point with a map of the explored zone without any assistance from the remote PC. If the Wi-fi connection with the PC is available, each NAO sends the current version of the environment map, the pictures and the sound it gets from cameras and microphones to the PC. If the PC recognizes objects or sounds, it sends the identifier back to the NAO that takes it into account.

The role of the remote PC is then to get information from the three NAO: pictures, sounds and maps. Based on a database of pictures and sounds, the identification of objects in the pictures and of audio events in the sounds is realized. The identified items are sent back to the robot that detected it. Collecting the maps from the three robots, the

PC merges them and processes them to build a complete and nice looking map. This improved map is not sent back to each robot because they don't really need it for their exploration task.

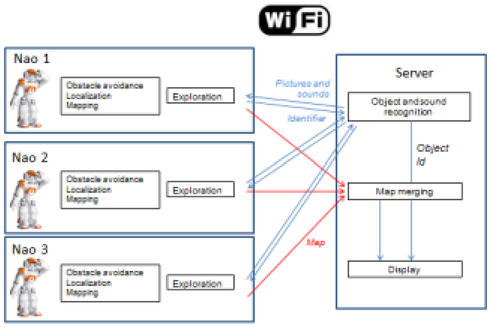

Figure 2 : Overview of the architecture

Providing the complete map to all the robots could be interesting to optimize the exploration with the three robots. It could happen that a robot that did not detect a zone to be explored would be closer to this zone than the robot that detected it. CEA started some work about this optimization of the exploration. It happened to be very interesting but quite complex while the benefit was not so relevant. Considering the size of the environment to explore and the real situations we faced, a simple heuristic at the beginning of the exploration appeared to be efficient enough : for its first choice robot 1 goes on the right, robot 2 goes in front and robot 3 goes on the left.

Operations

Based on this architecture, each robot before moving scans the environment with the laser and the cameras. It sends the pictures to the remote PC. Using the laser scan, it consolidates its map of the environment and look for new points to explore (holes in the map). It selects the more relevant point to explore and walk towards it. While walking, NAO uses the laser information to localize itself in its map. The obstacle avoidance uses the information coming from the ultra-sonic sensors and the bumpers that can detect objects invisible for the laser (glass, small objects on the ground). But obstacles can be detected as well by the object recognition running on the remote PC. The robot takes pictures of the ground in front of it. The ground can be recognized as dangerous (loose soil, gravel) according to the video classifier. Receiving this information, the robot is able to avoid walking on unsafe ground. All the recognized objects are stored in the map.

Conclusion

The system gave very good results and, for the third year of the challenge, we got good explorations and good maps (even if we finished last because of technical problems during the final test). We have proven that the exploration of unknown environment was doable with a small humanoid robot. This point was not granted for the other teams and the organizers of the challenge at the very beginning of this adventure.

The only limit of the architecture is that objects can't be recognized if the Wi-fi connection is not available and this can be dangerous for the robot if it does not recognize dangerous ground. Considering the domestic applications that Aldebaran targets, the occurrence of dangerous ground is rather limited and, anyway, it is possible to have a good Wi-Fi covering at home.

Today, Aldebaran is focusing on the navigation based only on vision [3] because the laser sensor is quite expensive and heavy for NAO as a future product for a large market but the principle of the architecture presented here will be retained.

[1] D. Gouaillier, V. Hugel et al. Mechatronic design of NAO humanoid". IEEE Int. Conf. on Robotics and Automation. 2009

[2] M. Montemerlo, S. Thrun, D. Koller, and B. Wegbreit, "FastSLAM: a factored solution to the simultaneous localization and mapping problem," in Proceedings of the National conference on Artificial Intelligence.2002

[3] E. Wirbel, B. Steux, S. Bonnabel and A. de La Fortelle. Humanoid robot navigation: from a visual SLAM to a visual compass. ICNSC 2013: IEEE 10th International Conference on Networking, Sensing and Control. 2013