Accurate 6D Localization in Multi-Level Environments

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Abstract. We present an approach to humanoid localization in complex indoor environments consisting of different levels. To determine the 6D pose in a given 3D world model, we apply Monte Carlo localization based on laser and vision data. We developed a novel improved proposal distribution that leads to a highly accurate pose estimate. We evaluated our approach in experiments with a Nao humanoid navigating in a two-level environment connected by a spiral staircase.

1 Improved Proposals for Highly Accurate Localization

In this paper, we present a technique that enables a humanoid robot equipped with cameras and a laser range finder to autonomously navigate and climb staircases in multi-level environments. In contrast to other popular approaches (such as [1–3]) we use a standard platform robot without external sensors or specialized hardware components for the stair climbing task, and we do not modify the environment in order to help the robot to sense the stairs. Furthermore, we consider complex staircases that consist of many steps with a reasonable step height and handrails.

To navigate in such complex environments, the robot needs to accurately determine its pose while walking and stair climbing. We first evaluated a standard Monte Carlo localization (MCL) approach that fuses observations from the 2D laser scanner, an inertial measurement unit, and joint encoders in order to localize the robot within a previously learned 3D model of the environment based on octrees [4, 5]. As our experiments show, the approach provides an accurate pose estimate while walking on flat ground. However, due to more inaccurate odometry information resulting from slippage on the stairs and map discretization effects, the performance degrades while climbing stairs. Recently, we presented an extension of MCL that additionally integrates information from images acquired with an on-board camera. This approach reconstructs a 3D model of the next step from observed edges and estimates the pose relative to the reconstructed stair model [6]. In this way, the accuracy was significantly increased, however, due to remaining uncertainties in the pose estimate on the stairs, the robot often has to actively verify its pose using contact sensors in its feet.

We therefore developed a new approach that draws particles from an improved proposal distribution, which yields a better representation of the robot's pose posterior distribution. The idea here is to calculate a proposal distribution based on laser and vision observations. In particular, we evaluate sampled points to fit a Gaussian to the proposal, and draw new particle poses from this Gaussian. To evaluate the particles, we use an observation model based on raycasting for laser measurements and chamfer matching for vision data. The visual observation model fits an edge model of the staircase consistently to a set of images instead of relying on local edge associations as in our previous work [6].

We thoroughly evaluated our localization approach in real-world experiments. The results show that our extensions to the standard MCL approach improve the localization accuracy significantly and enable the robot to highly accurately determine its pose. The robot can reliably navigate in our environment and climb the spiral staircase as shown in Fig. 1.

Fig. 1. *Left*: Camera image and projected staircase model based on the MCL pose estimate. The pose estimate is highly accurate as the model edges fit the edges in the camera image. *Right*: Nao climbs up a spiral staircase using our approach.

References

1. Chestnutt, J., Takaoka, Y., Suga, K., Nishiwaki, K., Kuffner, J., Kagami, S.: Biped navigation in rough environments using on-board sensing. In: Proc. of the IEEE/RSJ Int. Conf. on Intelligent Robots and Systems (IROS). (2009)
2. Cupec, R., Schmidt, G., Lorch, O.: Experiments in vision-guided robot walking in a structured scenario. In: Proc. of the IEEE Int. Symp. on Industrial Electronics. Volume 4. (June 2005) 1581 – 1586
3. Hirai, K., Hirose, M., Haikawa, Y., Takenaka, T.: The development of Honda humanoid robot. In: Proc. of the IEEE Int. Conf. on Robotics & Automation. (1998)
4. Hornung, A., Wurm, K.M., Bennewitz, M.: Humanoid robot localization in complex indoor environments. In: Proc. of the IEEE/RSJ Int. Conf. on Intelligent Robots and Systems (IROS). (2010)
5. Oßwald, S., Gutmann, J.S., Hornung, A., Bennewitz, M.: From 3D point clouds to climbing stairs: A comparison of plane segmentation approaches for humanoids. In: Proc. of the IEEE-RAS Int. Conf. on Humanoid Robots (Humanoids). (2011)
6. Oßwald, S., Görög, A., Hornung, A., Bennewitz, M.: Autonomous climbing of spiral staircases with humanoids. In: Proc. of the IEEE/RSJ Int. Conf. on Intelligent Robots and Systems (IROS). (2011)