Balázs Kégl
Guy Lapalme (Eds.)

LNAI 3501

Advances in Artificial Intelligence

18th Conference of the Canadian Society for Computational Studies of Intelligence, Canadian AI 2005 Victoria, Canada, May 2005, Proceedings

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Lecture Notes in Artificial Intelligence 3501

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Preface

The 18th conference of the Canadian Society for the Computational Study of Intelligence (CSCSI) continued the success of its predecessors. This set of papers reflects the diversity of the Canadian AI community and its international partners.

AI 2005 attracted 135 high-quality submissions: 64 from Canada and 71 from around the world. Of these, eight were written in French. All submitted papers were thoroughly reviewed by at least three members of the Program Committee. A total of 30 contributions, accepted as long papers, and 19 as short papers are included in this volume.

We invited three distinguished researchers to give talks about their current research interests: Eric Brill from Microsoft Research, Craig Boutilier from the University of Toronto, and Henry Krautz from the University of Washington.

The organization of such a successful conference benefited from the collaboration of many individuals. Foremost, we would like to express our appreciation to the Program Committee members and external referees, who provided timely and significant reviews. To manage the submission and reviewing process we used the Paperdyne system, which was developed by Dirk Peters. We owe special thanks to Kellogg Booth and Tricia d'Entremont for handling the local arrangements and registration. We also thank Bruce Spencer and members of the CSCSI executive for all their efforts in making AI 2005 a successful conference.

May 2005

Balázs Kégl and Guy Lapalme

Préface

La dix-huitième édition de la conférence de la Société canadienne pour l'étude de l'intelligence par ordinateur (SCEIO) poursuit la longue tradition de succès des ses prédécesseurs. Cet ensemble d'articles est un témoignage à la diversité des intérêts des chercheurs canadiens et internationaux.

AI 2005 a suscité 135 soumissions de haute qualité: 64 du Canada et 71 d'ailleurs dans le monde. 8 de ces articles ont été soumis en français. Tous les articles ont été relus et annotés par au moins trois membres du comité de programme. 30 contributions, acceptés comme articles longs, et 19 comme articles courts sont inclus dans ce livre.

Nous avons invité trois chercheurs réputés à venir présenter leurs intérêts de recherche actuels: Eric Brill de Microsoft Research, Craig Boutilier de l'Université de Toronto et Henry Krautz de l'Université de Washington.

L'organisation de cette conférence a profité de la collaboration de plusieurs personnes. Tout d'abord, nous remercions le comité de programme et les arbitres externes qui ont retourné des commentaires motivés et étoffés à l'intérieur de délais très courts. Pour la gestion des contributions et des commentaires, nous avons utilisé le système Paperdyne développé par Dirk Peters. Nous remercions spécialement Kellogg Booth and Tricia d'Entremont pour la gestion locale de la conférence et de l'enregistrement. Nous remercions également Bruce Spencer et les autres membres de l'exécutif de la SCIAEIO pour leurs efforts et leur collaboration pour le succès de AI 2005.

Mai 2005 *Balázs Kégl et Guy Lapalme*

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Dynamic Maps in Monte Carlo Localization

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Abstract. Mobile robot localization is the problem of tracking a moving robot through an environment given inaccurate sensor data and knowledge of the robot's motion. Monte Carlo Localization (MCL) is a popular probabilistic method of solving the localization problem. By using a Bayesian formulation of the problem, the robot's belief is represented by a set of weighted samples and updated according to motion and sensor information. One problem with MCL is that it requires a static map of the environment. While it is robust to errors in the map, they necessarily make the results less accurate. This article presents a method for updating the map dynamically during the process of localization, without requiring a severe increase in running time. Ordinarily, if the environment changes, the map must be recreated with user input. With the approach described here, it is possible for the robot to dynamically update the map without requiring user intervention or a significant amount of processing.

1 Introduction

In order for a mobile robot to accomplish anything in the world, it must know its own location and be able to determine the results of its motion. Localization is the name given to the problem of tracking a mobile robot given a map of the environment and the robot's sensor readings. If the robot's sensors worked perfectly, localization would be an easy task, since the odometers would give the exact location. The problem is that no sensor is perfect and the errors in odometer readings may be large. Another common sensor for a robot to have is some kind of range sensor. Sonars and laser rangefinders are two popular devices for localization. These sensors report the distance to the nearest wall but, like the odometers, they are prone to errors. Localization is the problem of compensating for the errors in odometry and sensor data in order to accurately determine the robot's location.

One solution to localization uses particle filters to represent the robot's location. The particle filter approach is known as Monte Carlo Localization (MCL) [3]. One problem with MCL is that it requires a static map of the environment. Sensor readings are compared with the expected values from the map and the comparison generates the probability of the robot's location. Errors in the map are partially compensated for by increasing the error that is assumed for the sensors. Another way to compensate for map errors is that the number of correct sensor readings will probably overrule incorrect ones. However, because MCL combines sensor error and map error, as map error

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increases, the allowable sensor error decreases until finally the algorithm fails and the map must be rescanned. Each error in the map is usually a minor matter for a localized robot; it is the combination of minor errors that can cause problems.

A localized robot rarely becomes mislocalized due to map errors, but this is not true of global localization, where the robot's initial location is unknown. Especially in symmetric environments, global localization can easily fail due to minor map errors that would be ignored by a localized robot.

The approach described in this article is based on the idea that if a robot is localized it may reasonably expect its sensor data to reflect the environment. If that is the case, then it should be possible to update the map according to the sensor data. If a known error in the map is fixed, then the robot will have a greater ability to deal with any subsequent errors. Since global localization may depend heavily on minor features, having an updated map can be a great benefit.

2 Background

2.1 Recursive Bayes Filter

Monte Carlo Localization is an implementation of a recursive Bayes filter. It estimates the posterior distribution of robot poses as conditioned by the sensor data. The key assumption is the Markovian assumption that, given the present, past and future are independent. In terms of localization, it means that if the current location of the robot is known, its future location does not depend on where it has been. Although this may not be completely true, it is a reasonable assumption to make.

Bayes filtering estimates the belief, which is the probability over the state space as conditioned by the data. This posterior is represented as:

$$Bel(x_t) = p(x_t \mid z_t, z_{t-1}..., z_0, u_t, u_{t-1},..., u_0) \tag{1}$$

x_t is the location at time t, z_t is the sensor data at time t and u_t is the motion data at time t. Sensor data is usually some form of range data, such as laser rangefinder data, while motion data is the robot's odometry readings from time t – 1 until time t.

Given the definition in (1), MCL uses a recursive Bayes filter to determine $Bel(x_t)$. In order to determine something recursively we need a recursive formula. Let $a^t = a_t,\ldots,a_0$, then equation (1) is converted using Bayes rule, the Markovian assumption, and integration into:

$$Bel(x_t) = \eta p(z_t \mid x_t) \int p(x_t \mid x_{t-1}, u_t) p(x_{t-1} \mid z^{t-1}, u^{t-1}) \tag{2}$$

where h is a normalizer constant.

Obviously, $p(x_{t-1}|u^{t-1},z^{t-1})$ is $Bel(x_{t-1})$, the prior belief of the robot's location, so we have our recursive equation. $p(x_t|u_t,x_{t-1})$ is the motion model. It represents the probability of moving to a specific location given the prior location and the motion reported by the odometers. Finally, $p(z_t|x_t)$ is the sensor model, representing the probability of receiving a specific sensor reading given the robot's position in the environment. These two models are determined by the hardware of the robot and an approximation must be created experimentally.