Technion – Israel Institute of Technology



Vadim Indelman, Luca Carlone, and Frank Dellaert

International Journal of Robotics Research *-* 2015

|  |  |  |
| --- | --- | --- |
| Alon Spinner | 305184335 | alonspinner@gmail.com |
| Dan Hazan | 308553601 | Danhazzan4@gmail.com |

June 19, 2022

# Introduction and Motivation

This work investigates the problem of planning under uncertainty with application to mobile robotics. It proposes a general framework where the robot bases its decisions on probabilistic description of its own state and of external variables of interest - on the general belief space (GBS).  
Common applications for such work include path planning, active exploration and "next best view".

|  |  |  |
| --- | --- | --- |
| A picture containing chart  Description automatically generated | Chart  Description automatically generated with medium confidence | Shape, rectangle  Description automatically generated |
| Next best view | Active Exploration | Path Planning |

There are three limitations that are common in the related work that the authors do not partake in: discretization, maximum likelihood assumption and the availability of prior knowledge. The proposed method relays on a dual-layer architecture: an inner layer that infers a cost of some future GBS for a given set of actions, and an outer layer which optimizes those set of actions.

The authors research their proposed method using a simulation of a UAV that hovers above an unknown environment and is required to reach goals without passing some localization uncertainty limit.

A picture containing text, sky, outdoor, shore

Description automatically generated

# General Belief Space Inference (SLAM)

To understand how one performs inference on GBS in the future, we first focus on GBS inference in the present.  
We focus on the researched example, of a UAV hovering over unknown terrain, the GBS is over a state of UAV poses and landmarks.

Diagram

Description automatically generated

Text

Description automatically generated

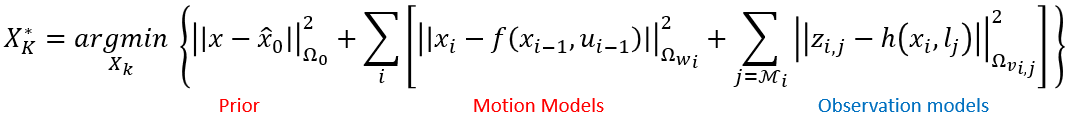
Given a collection of measurements and actions (data history) and motion and observation models, one can factor the inference problem as follows:

Diagram

Description automatically generated

Assuming the priors, motion model and observation models are all gaussian in nature, the posterior distribution over the state is also gaussian. The maximum a-posterior can then be found via expectation maximization, an approach that leads to a solution by least mean squares.

Diagram, schematic

Description automatically generated

As this is a non-linear least squares problem, the popular approach for a solution follows an iterative Gauss–Newton or Levenberg–Marquardt. In those, one is required to linearize the cost function on some point and optimizes around it in optimization step.

Text

Description automatically generatedText

Description automatically generated



A picture containing diagram

Description automatically generated

A key observation of which the authors take advantage, is that for the first optimization iteration, the matrix is not a function of the measurements.

# Planning in the General Belief Space

The authors suggest an algorithm that use the GBS to obtain the best set of actions given an objective function .

A picture containing text

Description automatically generated

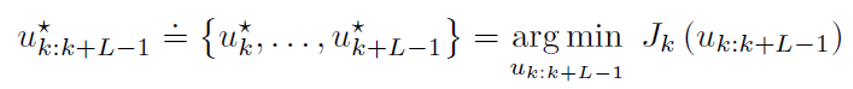
This algorithm use a dual-layer architecture that called inner and outer layers.

A picture containing diagram

Description automatically generated

Text

Description automatically generated



## Outer Layer

The outer layer is responsible for updating the set of actions given the objective function . We want to minimize and in order to do that the authors use gradient decent method.

Text

Description automatically generatedA picture containing diagram

Description automatically generated

Diagram

Description automatically generated with medium confidence

Text

Description automatically generated

Diagram, schematic

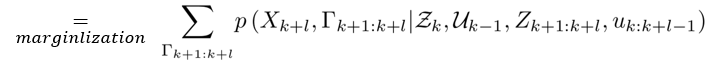
Description automatically generated

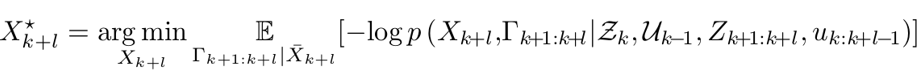
Text

Description automatically generated

## Inner Layer







# Diagram, schematic Description automatically generated

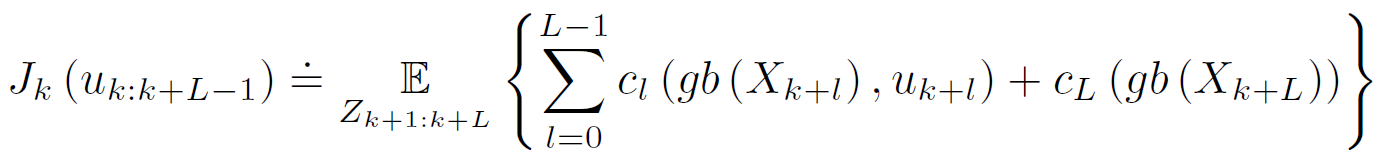
A picture containing text

Description automatically generated

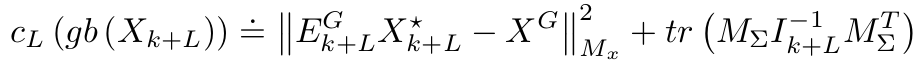
Diagram

Description automatically generated

# Formulating the Objective Function

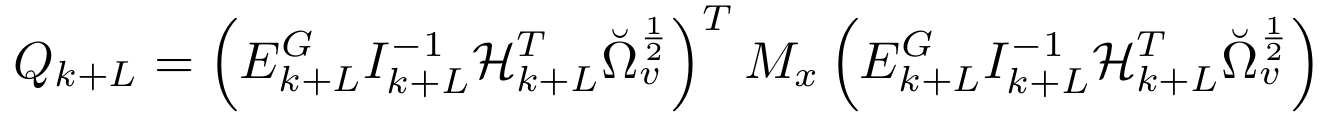






Diagram, schematic

Description automatically generated



## Choice of

Chart

Description automatically generated

## Choice of and







# Experimental Evaluation

Chart, scatter chart

Description automatically generated

# Implementation

Chart, scatter chart

Description automatically generated

# Possible Extensions

* Quadratic costs are problematic
* Hard constraints
* Loopy problems – adaptive beta
* For effiecicy:

Chart, radar chart

Description automatically generated