

IROS 2009 Tutorial: Filtering and Planning in I-Spaces PART 1: INTRODUCTION

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1. Introduction
 2. Physical Sensors
 3. Virtual Sensors
 4. Filtering
 5. Planning
 6. Possible Futures
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Follow along in the tutorial paper:

<http://msl.cs.uiuc.edu/~lavelle/iros09/paper.pdf>

Schedule and presentation slides:

<http://msl.cs.uiuc.edu/~lavelle/iros09/>

Support provided by:

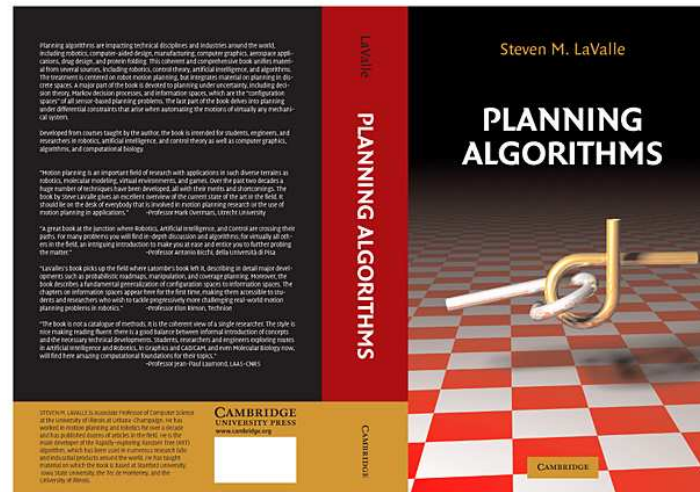
- *DARPA SToMP (Sensor Topology and Minimalist Planning)*
- *ONR/MURI IRIS (Inference in Reduced Information Spaces)*
- *NSF Robotics*

Why Am I Doing This?

I worked in planning for many years...since 1993 or so.

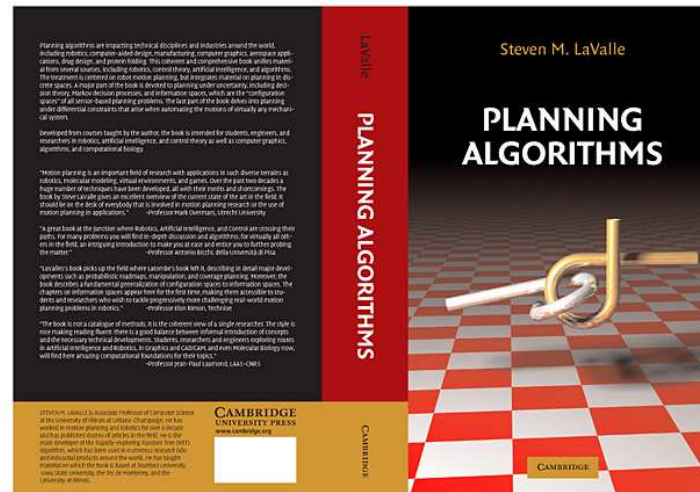
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I came to realize that sensing is often an afterthought in planning.
Information seems to “come for free” as input.
We plan in perfect C-spaces and state spaces with obstacles.

I-Spaces: The Next Generation of C-Spaces

When there are sensors, planning naturally lives in an *information space*.

We need to develop:

- Formulations of sensor models, I-spaces
- Models of complexity, computation over I-spaces
- Sampling-based planning methods
- Combinatorial planning methods

For C-spaces, the early steps were already done (Lagrangian mechanics).

Where Did Information Spaces Arise?

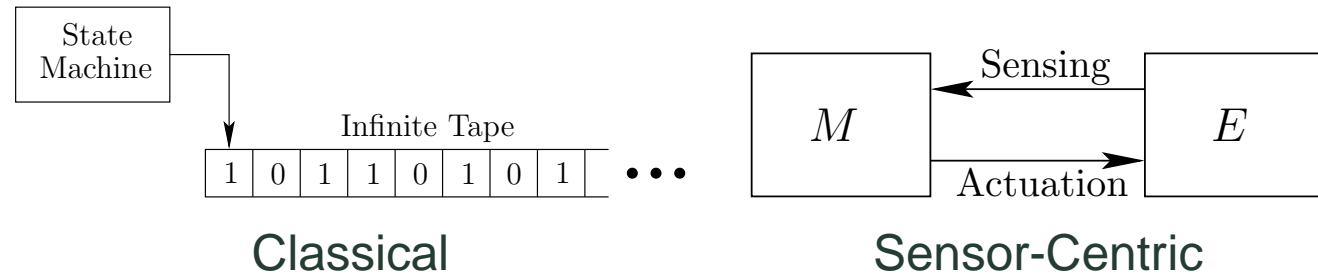
Where have *information spaces* arisen?

Early appearance of concept: H. Kuhn, 1953

- **Extensive form games**
Unknown state information regarding other players.
- **Stochastic control theory**
Disturbances in prediction and measurements cause imperfect state information.
- **Robotics/AI**
Uncertainty due to limited sensing.

Alternative names: belief states, knowledge states, hyperstates

Classical vs. Sensor-Centric Computation



Classical state: finite machine state, head position, and tape string

Sensor-centric state: internal, computational state and external, physical state

Depending on your background, there might be surprises in this tutorial:

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1. **Discrete vs. continuous: Not very important**
2. **Information spaces, not information theory**
3. **Perfectly accurate and reliable sensors yield huge amounts of uncertainty**

Some Coming Themes

- Start from the task and try to *understand* what information is actually *required* to be extracted from the physical world.
- We can design *combinatorial filters* that are structurally similar to Bayesian or Kalman filters, but dramatically simpler.
- There is no problem defining enormous physical state spaces, provided that we do not directly compute over them. However, state estimation or recovery of a particular state in a giant state space should be avoided if possible.
- Virtual sensor models provide a powerful intermediate abstraction that can be implemented by many alternative physical sensing systems.