CS 598JE: Computational Topology **Fall 2009**

Project Proposal 0 — November 02

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Minimalistic Tracking

Detecting and tracking multiple moving entities is of vital importance to several problems critical to society. For example, assisted living communities could benefit from the use of low-cost sensor platforms to monitor the movements of people in hospitals or homes. Other problems include tracking wildlife movement for conservation purposes, sensor-assisted child care, security, and retail marketing analysis. Previous tracking and detection systems have used powerful sensors and metric information to complete the task. Furthermore, such systems do not preserve user privacy, which is important in some applications.

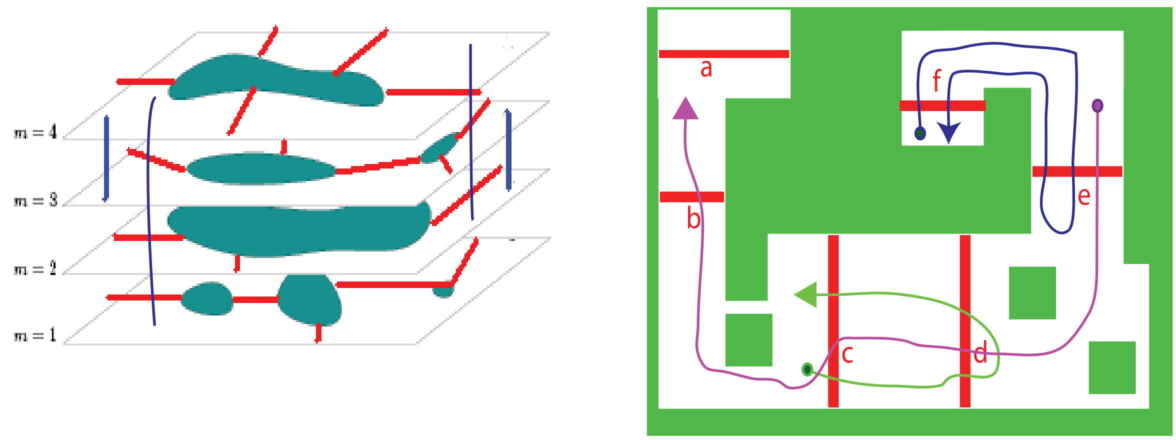

Figure 1. Four floors and three moving agents. Blue arcs represent conection between floors

Problem Formulation

The environment is a set $\mathscr{E}$ of m workspaces E_i (floors in a building) where each $E_i \subset \mathbb{R}^2$ is a polygonal region in the plane that has a connected open interior with polygonal holes that represent obstacles or inaccessible regions. Let $\mathscr{B}$ be a set of p pairwise disjoint *beams*, each of which is an open linear subset of and E_i. These beams are lines segments with both endpoints on the boundary of an E_i. For example in the Figure 1 the beams are labeled $B = \{a, b, c, d, e, f\}$.

Regions vertical connections and doors

The collection of obstacles (holes in the polygon) and beams induces a decomposition of E_i into connected *cells*. Since the beams are pairwise disjoint, each $B \in \mathscr{B}$ is a 1-cell. The 2-cells are maximal regions bounded by 1-cells and portions of the boundary of E_i. Every 2-cell is called a *region*; therefore, the polygon is decomposed into a set R of regions $r_1, r_2, \ldots r_p$. These regions are places of interest that can correspond, for example to rooms in buildings or sections. For example, the beams in figure 1 divide E into seven two-dimensional regions, $r_1, r_2, ..., r_7$. Let $R = \{r_1, r_2, ..., r_7\}$

We will also have vertical connections between two different floors E_i and E_j, as illustrated in the figure 1 by the blue arcs. This vertical connections allow agents to continue a path from one floor E_i to another E_j, these vertical connections represent doors, ramps and elevators in buildings.

There will be special edges $e \in E_i$ that allows agents to enter or exit the environment (ports), these edges represent doors in buildings.

Agent paths

There will be *n people* or *agents* moving along paths $\tilde{x}_i : [0, t_f] \to \mathscr{E}$, in which $[0, t_f]$ represents a time interval and t_f is the final time.

Sensor Word

Let L be a finite set of beam names, and each beam has unique label. Let $D = \{-1, 1\}$ be the set of beam directions. The sensor model depicted in Figure 1 can be obtained by a sensor mapping $h : \mathscr{E} \to Y$ in which $Y = (L \times D) \cup \{\epsilon\}$, in which ϵ corresponds to nothing being detected by the sensor.

We define $\tilde{y}$ to be the sequence of observations collected during a period of time $[0, t_f]$ from all the sensors. For example, in Figure 1 we have $L = \{a, b, c, d, e, f\}$. The beams are directed, so left-to-right and bottom-to-top are the forward directions. For example, the sensor word with the ϵ observations removed can be encoded as $\tilde{y} = e^{-1}d^{-1}c^{-1}b^{-1}cdd^{-1}c^{-1}fe^{-1}ef^{-1}$. For each $l \in L$, l denotes the forward direction and l^{-1} denotes the backward direction.

Open problem: Using $\tilde{y}$ is it possible to infer the strings $\tilde{y}_i$ for each agent?

Let $\tilde{y}_i$ the sequence of crossings for the i-th agent, for the example of Figure 1, $\tilde{y}_1$ (the blue agent) is $fe^{-1}ef^{-1}$ $\tilde{y}_2$ (pink agent) is $e^{-1}d^{-1}c^{-1}b^{-1}f$ and $\tilde{y}_3$ (green agent) is $cdd^{-1}c^{-1}$. Some interesting problems in this framework are:

- Given the cell decompositions induced by beams and obstacles, the number of agents n and $\tilde{y}$ present an algorithm to return a set of possible $\tilde{y}_i$?. Under what conditions is this possible?
- Given $\mathscr{E}$ return an ideal placement for $\mathscr{B}$ to better infer $\tilde{y}_i$

Related works in Computational Topology are testing homotopic paths [1] and normal curve representations [2]. In [3] algorithms for descriptions up to homotopy class and winding numbers around obstacles are presented for one agent in a planar workspace.

Bibliography

[1] Sergio Cabello, Yuanxin Liu, Andrea Mantler, and Jack Snoeyink. Testing homotopy for paths in the plane. *Discrete and Computational Geometry*, 31(1):61–81, 2004.

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[3] B. Tovar, F. Cohen, and S. M. LaValle. Sensor beams, obstacles, and possible paths. In *Proceedings Workshop on Algorithmic Foundations of Robotics (WAFR)*, 2008.