Novel methods for Motion Planning

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BUMP-SURFACES FOR OPTIMAL MOTION PLANNING [1] [2]

BUMP-SURFACE

- Represents entire 2D robot environment via tensor product B-Spline Surface.
- The path is represented by a B-Spline onto the Bump-Surface.
- Takes full advantage of these mathematical entities, especially control points.
- The final motion planning problem is formulated as a global optimization problem, solved using combination of Genetic Algorithms and Conjugate Gradient methods **[1]**.

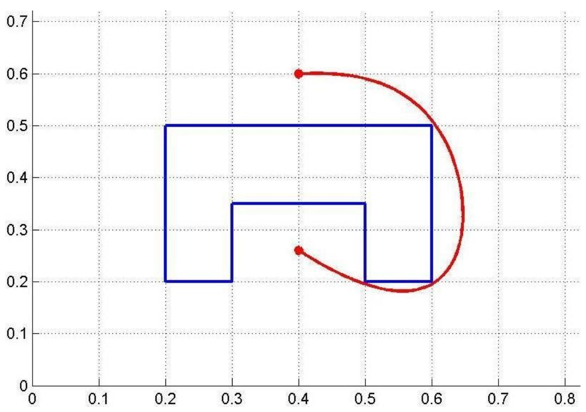

Fig. A1 - 2D environment with non-convex obstacle and robot's optimal path.

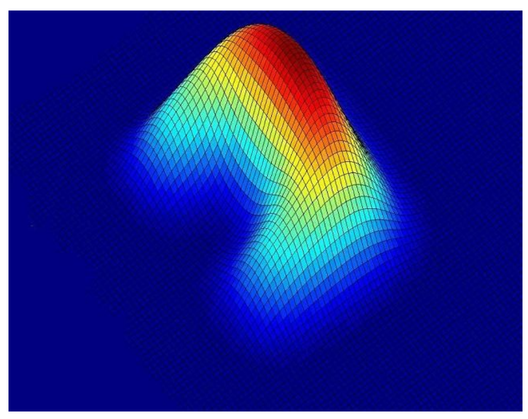

Fig. A2 - The corresponding Bump-Surface.

BUMP-HYPER SURFACE

- Extension of the Bump-Surface from 2D to 3D Euclidean space.

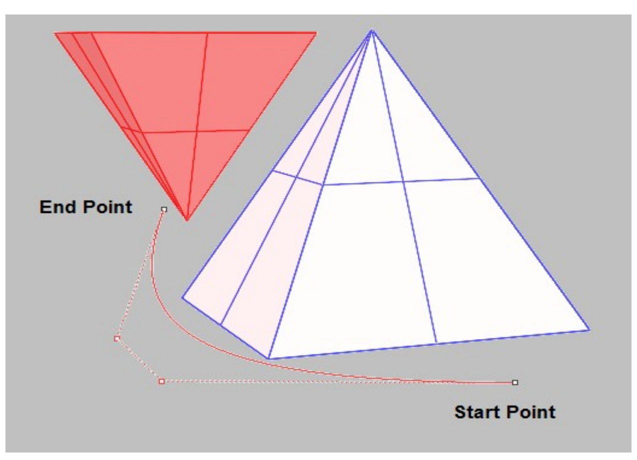

Fig. A3 – A 3D environment with polyhedral obstacles (pyramids) and determined optimal path. The path is defined by four control points: the start-point, two points at the space in-between and the end-point.

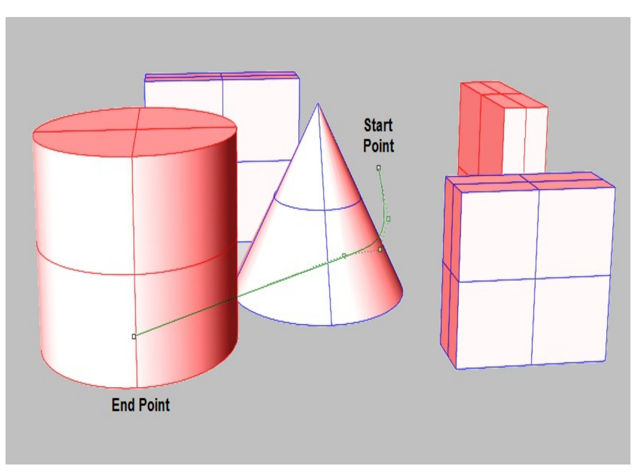

Fig. A4 – A 3D environment with polyhedral obstacles and the optimal path. The determined path is defined by means of six control points, all located in space $(x \neq 0, y \neq 0, z \neq 0)$

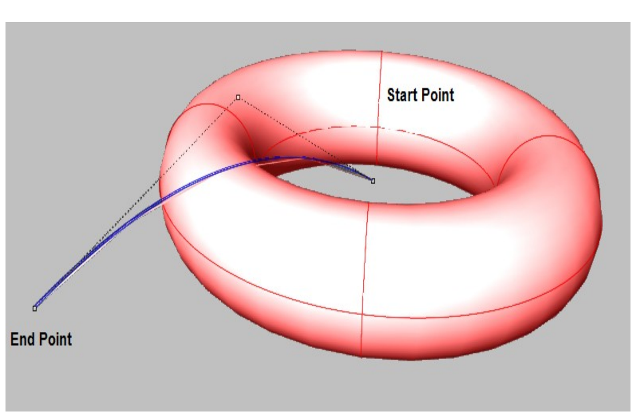

Fig. A5 - A 3D environment with a torus obstacle, where the start point is at the torus centre. The required path is defined by three control points: The start point, a middle point $(x \neq 0, y \neq 0, z \neq 0)$ **and the end point.**

CONCLUSIONS

- Computational time does not depend on the number of obstacles but on the size of the control parameters of the GAs and density of grid points **[2]**.
- The accuracy of the solution depends on the density of the grid points.
- An optimal path can be found even in significantly complicated environments, cluttered with obstacles of arbitrary size and location.
- The final path is always smooth and conformal to the objectives, so the robot can follow it avoiding jerky motions.

MULTI-AGENT BASED MANIPULATOR CONTROL AND MOVING OBSTACLE AVOIDANCE [3]

KINEMATIC MODEL

- Planar and 3D manipulators.
- With any serial combination of rotational and translational joints.
- Manipulator base may be fixed or may move freely or on predefined path.

CONCEPTUAL MODEL

- Potentially expandable rods (length Li in [Li-min, Li-max]).
- Rods connected at their endpoints using pins (angle Ai in [Ai-min, Ai-max]).
- Forming a chain that behaves like a rope (given high number of rods & pins).

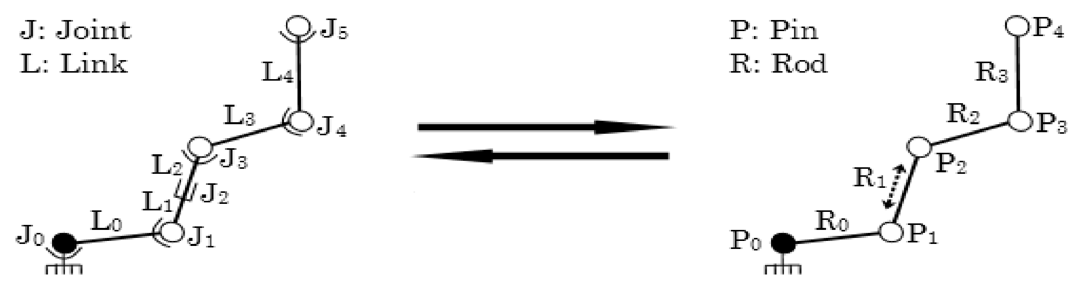

Fig. B1 – conceptual model maintaining a 1-1 mapping with the kinematic model and its constraints.

CHANGE EVENT PROPAGATION

- Any chain part (not only the tool tip) can initiate motion, via commands of planner module or human operator: chain is split by mover in two sub-chains.
- A slave has its own slave (master-slave hierarchy, nested relationships).
- Each slave tries to react and adapt to its master's state change event **[3]**.

Fig. B2 - State change events at the head of each sub-chain propagate towards its tail.

REACTION TO MASTER'S STATE CHANGE EVENTS

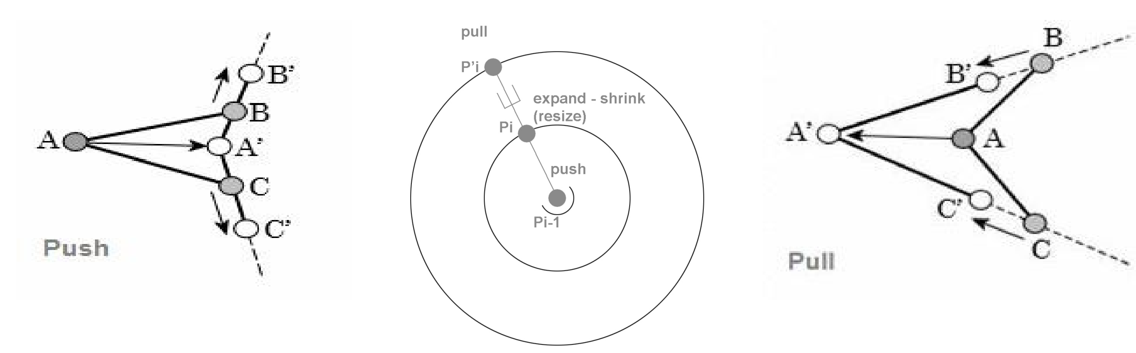

Fig. B3 - Two basic constraint preservation behaviors: Push & Pull. Slave moves on guiding line.

REACTION TO SENSED OBSTACLES

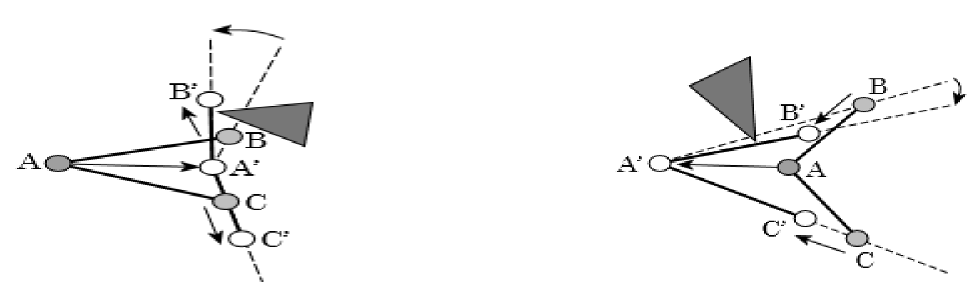

Fig. B4 - Guiding line for slave motion rotates around master pin, to avoid "contact" with obstacle.

REFERENCES

1. P.N. Azariadis, N.A. Aspragathos, *"Obstacle Representation by Bump-Surfaces for Optimal Path-Planning"*, Journal of Robotics and Autonomous Systems (accepted for publication).
2. E. Xydias, N.A. Aspragathos (2004), *"Bump-Hyper Surfaces For Optimal Motion Planning in Three Dimensional Spaces"*, RAAD 04, Brno, 2-5 June 2004.
3. G.I. Birbilis, N.A. Aspragathos (2004), *"Multi-Agent Manipulator Control and Moving Obstacle Avoidance"*, ARK 04, Sestri Levante, Italy, 28 June – 1 July 2004.