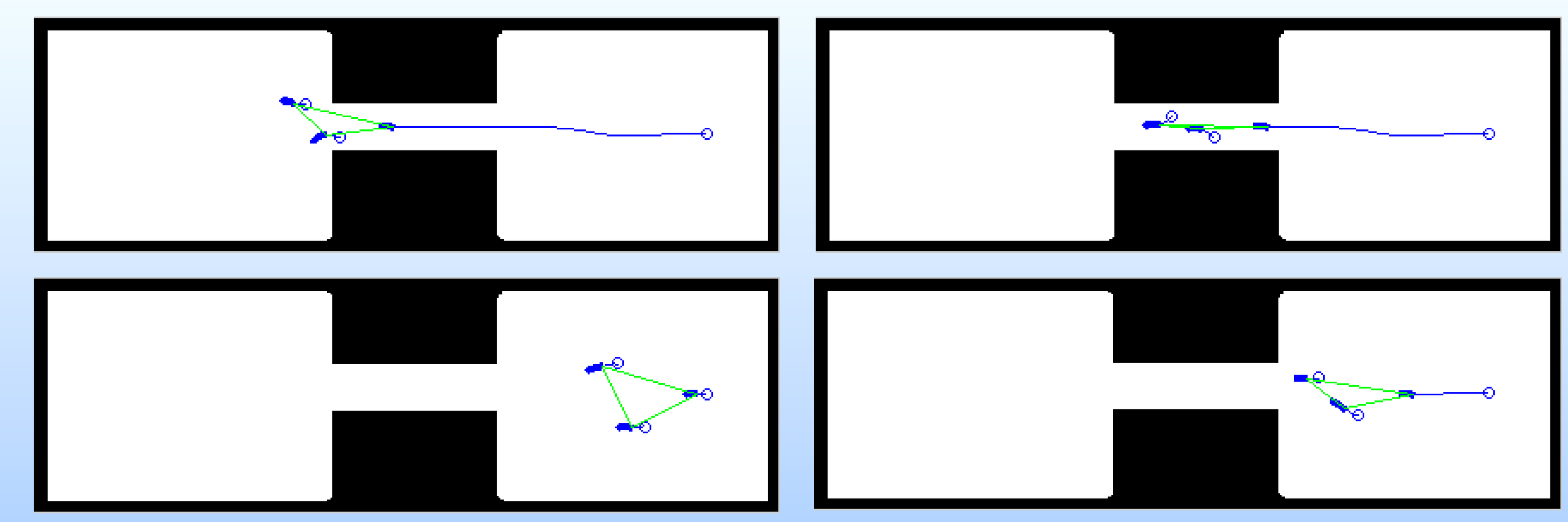
ADAPTIVE ROBOT FORMATIONS USING FAST MARCHING SQUARE WORKING UNDER UNCERTAINTY CONDITIONS

Javier V. Gomez — jvgomez@pa.uc3m.es
Santiago Garrido — sgarrido@ing.uc3m.es
Luis Moreno — moreno@ing.uc3m.es
Robotics Lab. Carlos III University of Madrid

INTRODUCTION

Nowadays a single robot is able to perform very complex tasks on its own but some of these tasks can be perfomed in a more efficent way using a group of robots. Therefore applying robot formations to risky or complex tasks can improve their development and can save time, money, increase safety in some kind of jobs and dangerous situations or even save lives.

It is required to design an algorithm robust enough to give an acceptable, fast response in every kind of environment conditions even when the uncertainties in robots and obstacles positions are high.



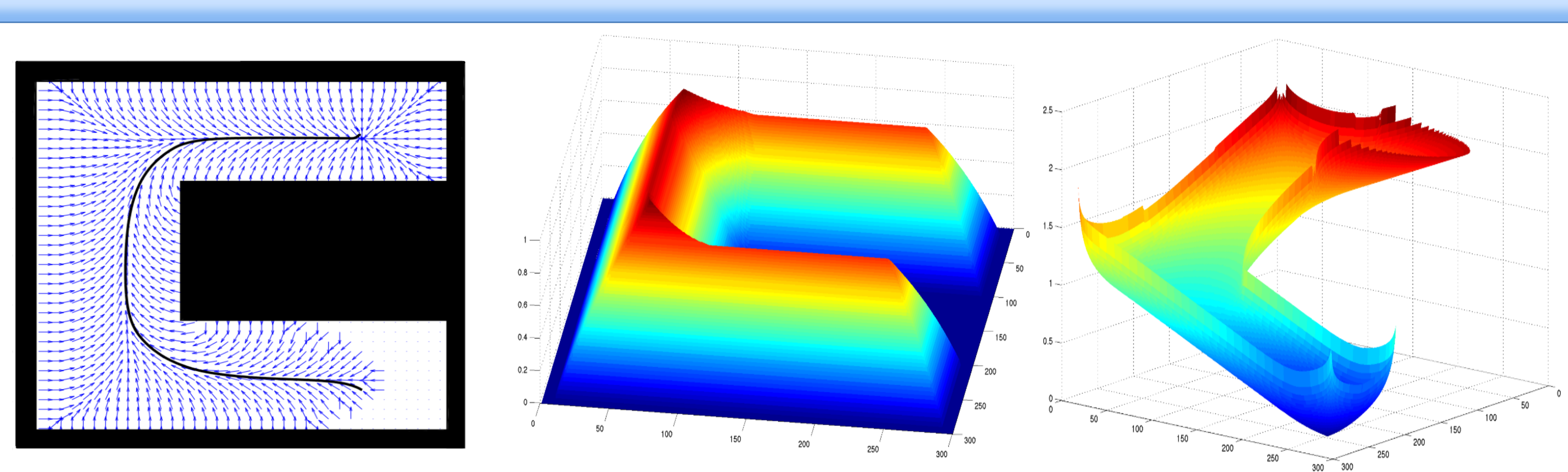
FAST MARCHING SQUARE

A reliable algorithm to plan robot formations motion requires a good path planning method. Fast Marching Square (FM^2) [1], an artificial potential path finding method has been chosen due to its efficiency and robustness. It is based on applying the Fast Marching method [2] twice over the same map. Its key characteristics are:

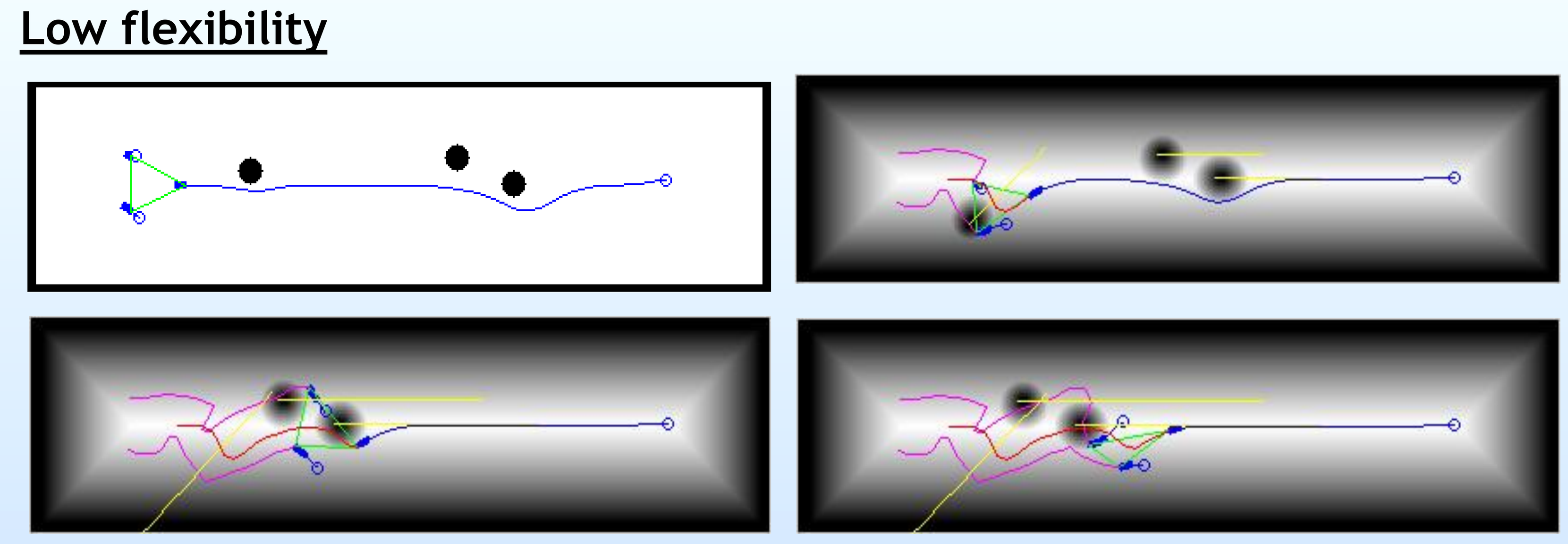
- Absence of local minima.
- Completeness.
- Fast response.
- Reliable, smooth and safe trajectories.

Fast Marching Square Algorithm

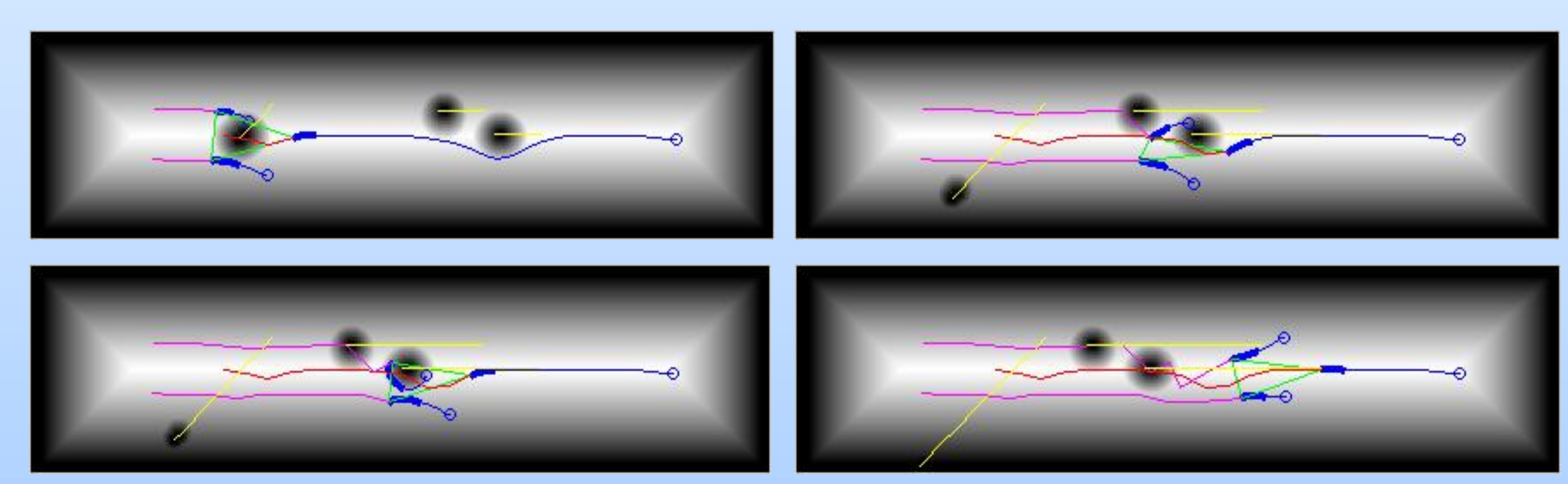
Model the environment → Enlarge obstacles → FM 1st: slowness potential **W** → FM 2nd: distance potential **D** in metrics **W** → Extract the path: gradient method



Low flexibility



High flexibility



ROBOT FORMATIONS AND FM^2

The final objective in robot formations is to find the paths and postures (positions and angles) for each robot of the formation, taking into account the characteristics of the environment, the other robots and the final objective. Leader-followers architecture has been chosen between the different existing methods to plan formations motion. The method proposed herein can be applied to a big formations even with virtual leaders.

Obtain the complete path for the leader → Each robot includes the obstacles and other robots in its **W** map with an uncertainty function → Calculate the partial goal for each follower according to the prescribed geometry of the formation → Adjust the distance from the leader proportional to the **W** value → Obtain the followers path with FM^2 → Move the robots a fixed number of steps → Obtain the complete path for the leader

Managing Uncertainties

Uncertainties (in obstacles and robots positions and velocities) are modeled by means of *uncertainty functions*, which represent the probability of the robot/obstacle to be in that point. These uncertainty functions are created using the standard FM algorithm and they are included in the **W** map in the FM 1st step of the FM^2 method. Thus the robot avoid:

- To go far from places where there are not any obstacles but the velocity is slow.
- To go far from places where the velocity can be high but it is not possible to ensure that it is clear space.

The proposed algorithm also allows to include uncertainty with mobile obstacles, using the same uncertainty functions deformed in the direction of the movement. It is possible to set the flexibility of the formation setting the distance of the robots to their partial objectives.

ROBOT FORMATIONS IN SOCIETY

The proposed algorithm bring closer the real applications of the robot formations due it robustness and the low complexity. The applications of robot formations and their impact in society can change the world as we know it, making risky tasks safer. For example, some of the main applications could be:

- **Surveillance.** A formation of robots can explore a wider area, faster and in a more efficient way than humans. Also in low light conditions due the current sensor technologies.
- **Search and rescue.** As a consequence of the previous point. Faster exploration can mean to find survivors faster in disasters. Also a employing a robot formation allows to create a map to help emergency personnel to plan the action.
- **Evacuation.** In cases where a massive evacuation is needed (i.e. fires) a robot formation can guide people to the exit using the safest possible way thanks to the FM^2 method. Using a formation makes this task easier since the people has more than one guide to follow. Also the robots can be equipped with tools to remove debris, cleaning the path better than only one robot.
- **Industry and manufacturing.** To manufacture or move big pieces a robot formation with low flexibility can be employed.
- **Bodyguard.** In this case, a human acts as a leader of the formation and the robots move around him. Robots can react faster than humans, so the safeness of the human is increased and also injuries to human bodyguards are avoided.

Therefore, applying robot formations to risky or complex tasks can improve their development and can save time, money, increase safety in some kind of jobs and dangerous situations or even safe lives.

References:

[1] S. Garrido, L. Moreno, M. Abderrahim and D. Blanco, "FM2: A Real-time Sensor-based Feedback Controller for Mobile Robots", *International Journal of Robotics and Automation*, 2009, vol. 24, issue 1, pp. 3169-2192.

[2] J. A. Sethian, "A Fast Marching Level Set Method for Monotonically Advancing Fronts", *Proceedings of the National Academy of Science*, 1996, vol. 93, issue 4, pp. 1591-1595.