University of Applied Sciences
HOCHSCHULE EMDEN·LEER

# Mobile Robotics

Prof. Dr.-Ing. Gavin Kane

# Introduction to Mobile Robotics

## Lecture Content

- Organisation
- Motivation / Definitions
- History
- Use cases
  - Commercial Examples
  - Research Examples
- Components of a Mobile Robot
- Short view of Algorithms required for Autonomous Behaviour
  - Probabilistics
  - Algorithms / Filters / SLAM

# Introduction to Mobile Robotics

## Course Organisation

- Mondays, 08:00 in S5 - Practical
- Tuesdays, 10:00 in S209 - Theory

## Project Work

- Examination Through Project Work
- Moodle Based Submission, Course Number: 5060 - MB_SS20_GK
- Mobile Robotics SS2020
- Submission to occur before the End of Examination Block SS2020, 06.07.2020.

# Introduction to Mobile Robotics

## Course Goals

- Provide an overview of problems / approaches in mobile robotics
  - Path Planning
  - Kinematics / Odometry
  - Sense - Plan - Act
  - State Machine / PID Control
- Probabilistic reasoning: Dealing with noisy data
- Robot Operating System (ROS)
- Robot Design and Simulation
- Hands-on experience

# Introduction to Mobile Robotics

## Course Prerequisites

- Mathematics 1 and 2
- Programming 1 and 2
- C or Python
- Highly Desired:
  - MATLAB / Simulink
  - Mechatronics, Kinematics
  - Mathematics 3, Probability, Matrices
  - experience in Linux

# Introduction to Mobile Robotics

## Supporting Literature

1. P. Corke, Robotics, Vision and Control
   Springer-Verlag, 2. Auflage 2017
2. S. Thrun, W. Burgard, D. Fox, Probabalistic Robotics
   The MIT Press
3. S.J. Chapman, MATLAB Programming for Engineers
   Thomson, 3. Auflage 2004
4. Siegwart, Introduction to autonomous mobile robots
   MIT Press, 2011 (electronic coopy available in Library)
5. JC Latombe, Robot Motion Planning
   Kluwer Academic Publishers, 1991
6. Steven M. LaValle, Planning Algorithms
   Cambridge University Press
   http://planning.cs.uiuc.edu/

# Contents

Note: The Weekly Practical is actually on the Monday the following week, so as to support the theory after receiving it.

## Week 1

- Introduction (This lecture)
- Mobile Robot Paradigms
- State-Machine Control
- Week 1 Practical
  - MARS Robot

## Week 2

- Wheeled Locomotion
- Probability Revision
- Probabilistic Motion Models
- Second Practical Exercise
  - Position Control

## Week 3

- Probabilistic Sensor Models
- Third Practical Exercise
  - Sensor Models
  - Mapping Intro

## Week 4

- Mapping with known Positions
- Fourth Practical Exercise
  - Mapping with known Positions

# Contents, continued

## Week 5

- Path Planning
- Fifth Practical Exercise
  - Path Planning

## Week 6

- SLAM
- FastSLAM
- Graph based SLAM
- Sixth Practical Exercise
  - SLAM

## Week 7

- Robots in Industry
- No Practical this week

## Week 8

- Introduction to ROS
- ROS Practical Exercise - 1
  - ROS Environment Setup
  - ROS Commands
  - Catkin build

## Week 9

- ROS Publishers and Subscribers
- Actions and Servers
- ROS Practical Exercise - 2
  - Building a Publisher / Subscriber
  - Launch Files

# Contents, continued

## Week 10

- ROS Robot Environment Definition
- Kinematics / Robot State Publisher
- ROS Practical Exercise - 3
  - URDF
  - RVIZ

## Week 11

- Mapping
- Mobile Robot Movement
- ROS Practical Exercise - 4
  - Sensor Data
  - Mapping
  - Planning / Controlling
  - Gazebo

## Week 12

- Manipulation in ROS
- ROS Practical Exercise - 5
  - MoveIT Tutorial

## Week 13

- Perception in ROS
- ROS Practical Exercise - 6
  - ROS TF2 Package
  - Camera Perception Example

## Week 14

- Behaviours in ROS
- ROS Practical Exercise - 7
  - FlexBE

# Motivation

## Definition ”mobile Robot”

ISO 19649:2017 - Mobile Robots - Vocabulary

”A Robot able to travel under it’s own control”

## Definition ”mobile Platform”

ISO 8373:2012 - Robots and robotic devices - Vocabulary

”A mobile robot can be a mobile platform with or without manipulators.”

## Other definitions

- Platform with a large mobility within its environment (air, land, underwater …
- A System with the following functional characteristics:
  - Mobility: total mobility relative to the environment
  - A certain level of autonomy: limited human interaction
  - Perception ability: sensing and reacting in the environment

# Motivation

*"Menschen sind Maschinen der Engel."*

Jean Paul, 1785

## Definition "autonomous"

Cambridge Dictionary: 1. //ɔ:'tɒn.ə.məs <Adj.> [greek. autónomos, from: nómos = Rules]: a) independent and having the power to make your own decisions ...

## Autonomous Systems

- can perform tasks **without human interaction**
- are used for intelligent cars and robots
- require usage of a variety of sensors for understanding their environment
  - independant navigation
  - Perform manipulation from objects in their environment

# Mobile Robot Associated Norms

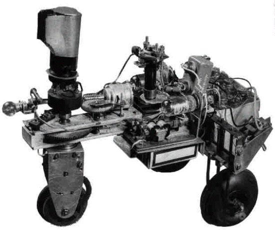
## Norms

- ISO 10218-1:2011
  - Robots and robotic devices – Safety requirements for industrial robots – Part 1: Robots
  - Industrieroboter - Sicherheitsanforderungen - Teil 1: Roboter
- ISO 10218-2:2011
  - Robots and robotic devices – Safety requirements for industrial robots – Part 2: Robot systems and integration
  - Industrieroboter - Sicherheitsanforderungen - Teil 2: Robotersysteme und Integration
- ISO 13482:2014
  - Robots and robotic devices – Safety requirements for personal care robots
  - Roboter und Robotikgeräte - Sicherheitsanforderungen für persönliche Assistenzroboter
- ISO/TS 15066:2016
  - Robots and robotic devices – Collaborative robots
  - Roboter und Robotikgeräte - Kollaborierende Roboter

# History

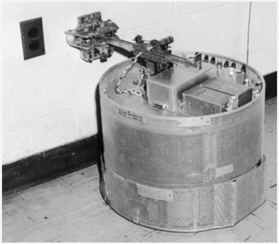
## 1948

W. Grey Walter built Elmer and Elsie, "Maschina Speculatrix"



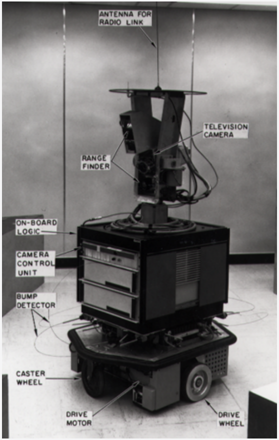
## 1960

John Hopkins University builds "The Beast"



## 1966-1972

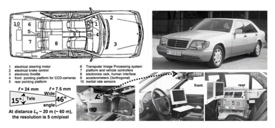
Standford develops "Shakey"



# History - 2

## 1994

### VAMP

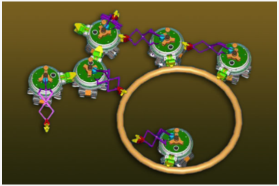


## 1997

### Mars Robots


## 2000

### Swarm Robots

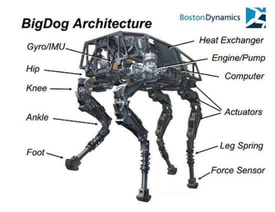


## 2000

### Household Robots


## 2005

### Big Dog

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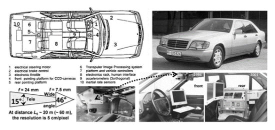
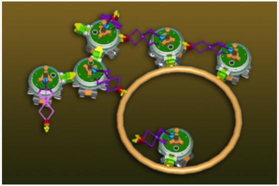


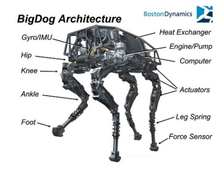
## 2000

### Swarm Robots



## 2005

### Big Dog




## 1997

### Mars Robots


## 2000

### Household Robots


## and...

## and...

## and...


## and...

# Practical Applications - 1

## Applications

Mobile Robot applications can be found in every area where a vehicle or Autonomous System could exist.

## Transport

- Personal
  - Personal 1 - Google Car
  - Personal 2 - Ehang
- Goods
  - General Transport
    - Warehouse Internal 1 - Swisslog
    - Warehouse Internal 1 - Amazon Warehouse
    - Warehouse to Warehouse
    - Warehouse to Customer - Amazon Prime Air
  - Spezialised
    - Medical Supplies 1 - Swisslog
    - Medical Supplies / Support 2 - TU Delft
    - Lifering delivery - RTS Lab
    - Large Item - Kuka
    - Car Parking - Yeefung

# Practical Applications - 2

## Cleaning

- House Cleaning - iRobot
- House Cleaning - Braava
- Lawnmowing - Husqvarna
- Glass Cleaning Robot - HOBOT

## Customer Service

- Restaurant Service
- Museem Guide
- Virtual Presence
- Emergency Assistance

## Agricultural

- Agricultural Robot - Bosch

## Mining Robots

- Deep Sea Mining - Video 1 , 2

## Entertainment

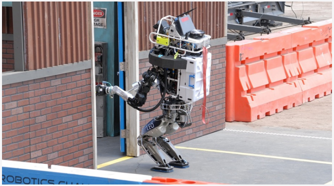
- Toy - Sony
- Home Companion - Kuri

## and....

# Research Project Examples

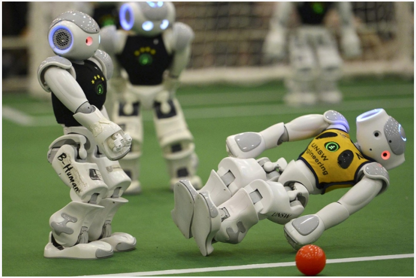
## Darpa

- Video



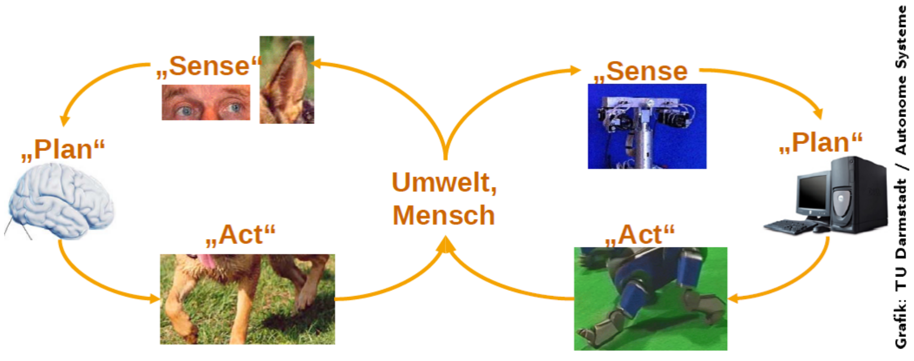
## Robot Soccer

- Video 1
- Video 2



# Robot Paradigms

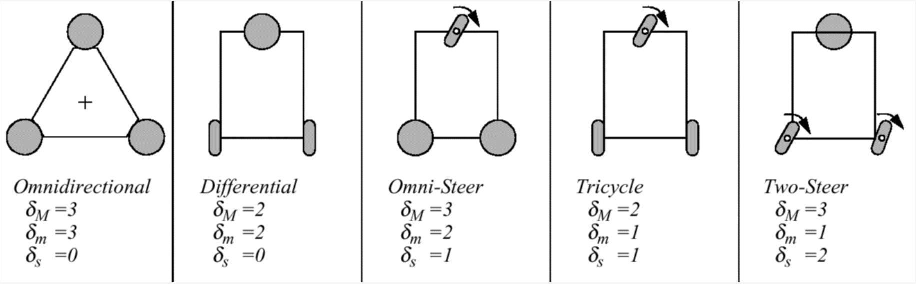
## Plan-Sense-Act-Cycle of a mobile Robot



# Wheeled Mobile Robot Kinematics

## Maneuverability = mobility + steerability

- Instantaneous Center of Curvature (3 = plane, 2 is line)
- The mobility available based on the sliding constraints plus additional freedom contributed by the steering



# Components of a Mobile Robot

## Mechatronic System

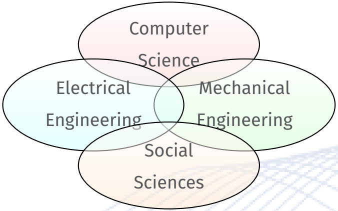
The implementation of a Sense-Plan-Act Cycle for autonomous Robots requires an interdisiplinary solution:

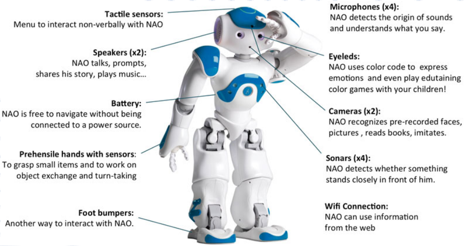
## Hardware

- Sensors
- Locomotion System
- Computational Power
- Communications

## Software

- Sensor Analysis
- Planning, at a number of different levels



# Short view of Algorithms required for Autonomous Behaviour

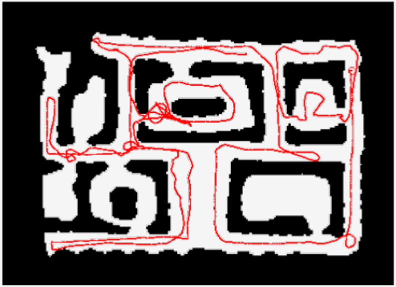
## Simultaneous Localisation and Mapping

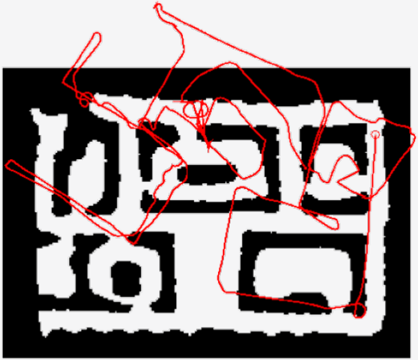
- A Chicken and the Egg Problem
- A Map is necessary in order to know where the robot is
- A known position is essential, in order to use sensor data to generate a map

# Short view of Algorithms required for Autonomous Behaviour

## Sensor and Sensor Models

- All Sensors deliver data with noise
- Errors in measurements will be integrated over time
- Decisions will need to be continually made based on the sensor information. Firstly how to interpret the information, and then what action to make based on it





# Short view of Algorithms required for Autonomous Behaviour

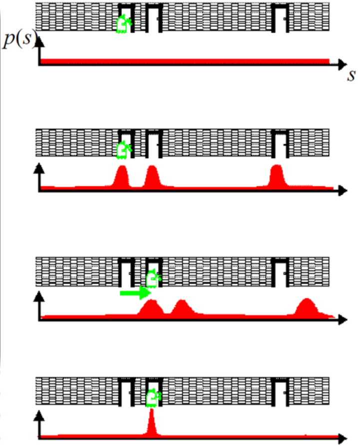
## Position Identification

Using Bayes Filter as a step to position identification

$$P(x|u) = \int P(x|u, x')P(x')dx \qquad (1)$$

and our belief:

$$Bel(x_t) = \eta P(z_t|x_t) \int P(x_t|u_t, x_{t-1})Bel(x_{t-1})dx_{t-1} \qquad (2)$$



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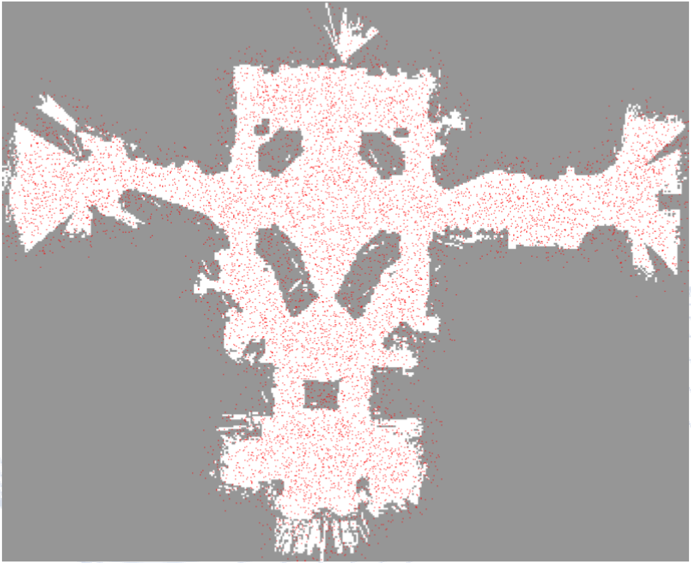

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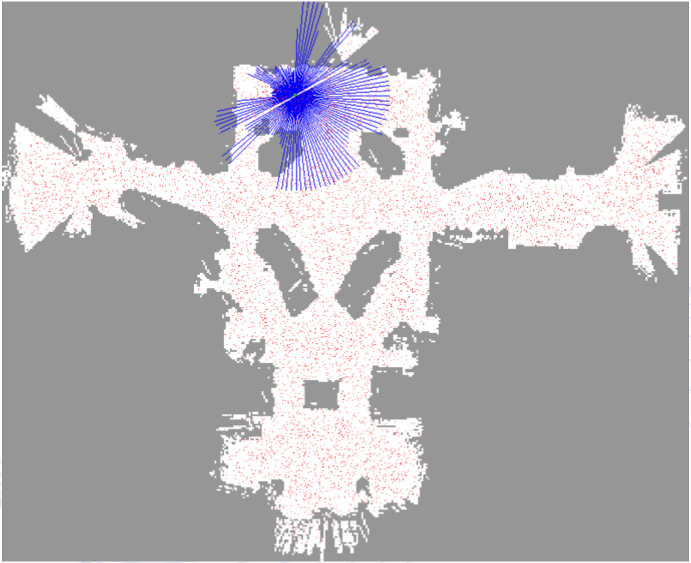

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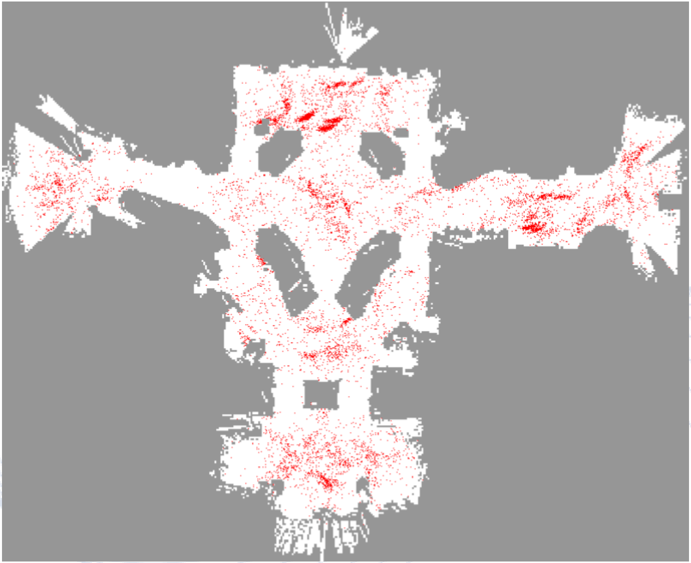

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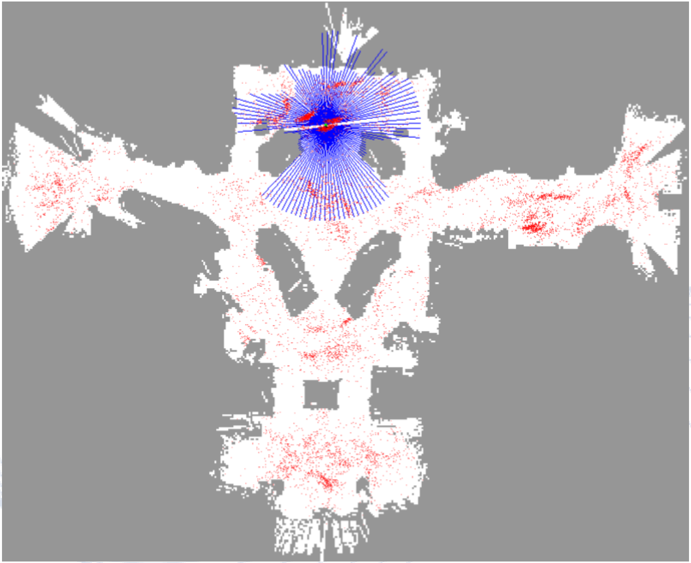

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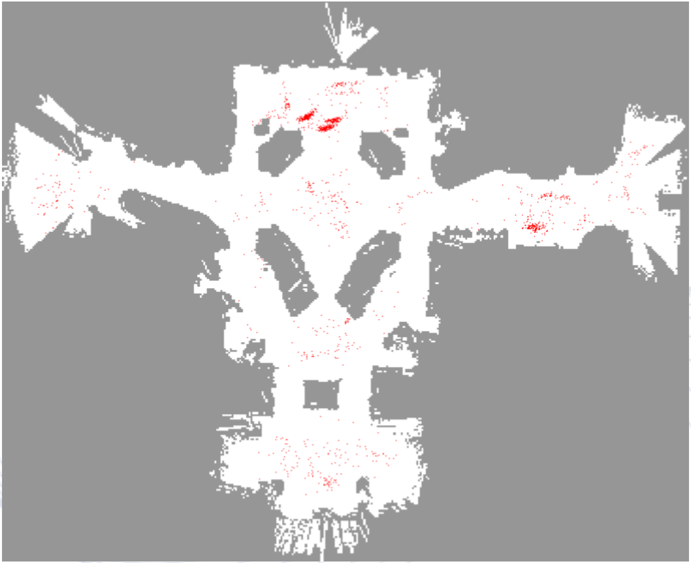

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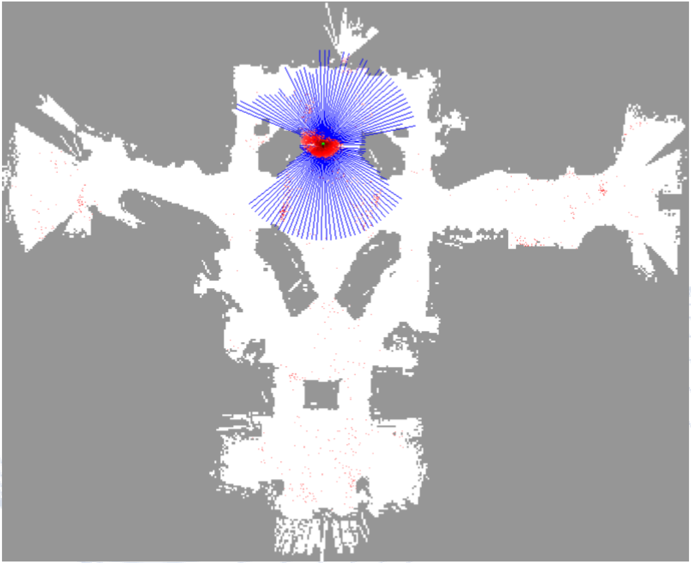

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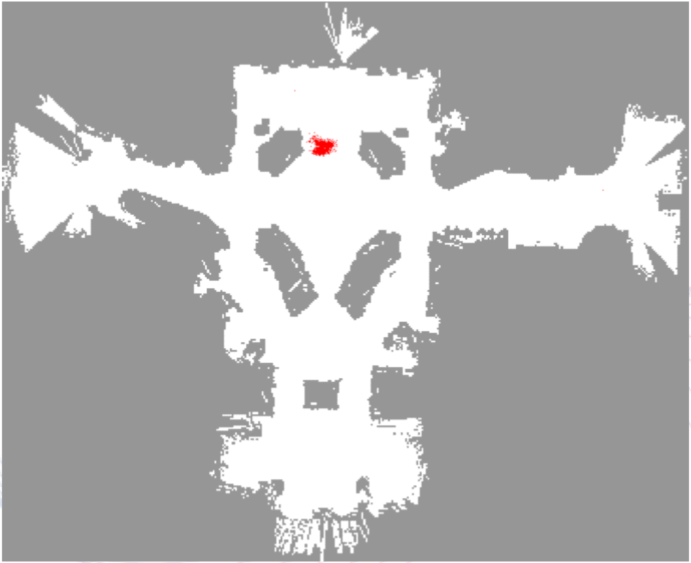

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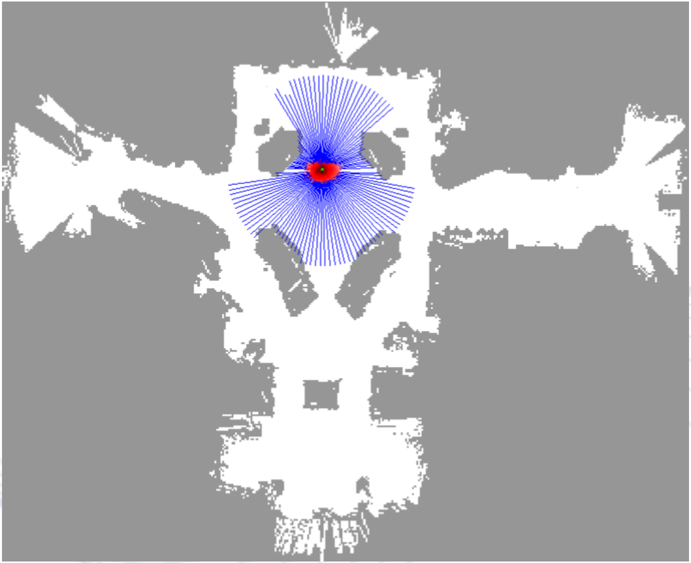

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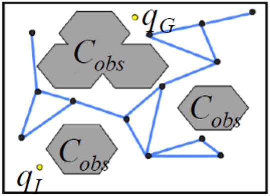
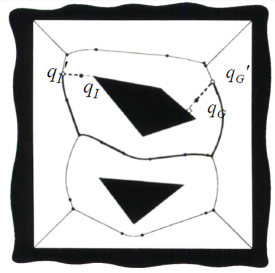
# Short view of Algorithms required for Autonomous Behaviour - Path Planning

## A*

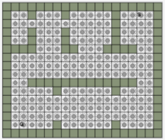
## Probabilistic Road Map (PRM)



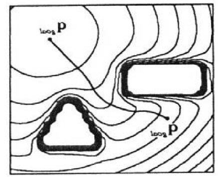

## Generalised Voronoi Diagram

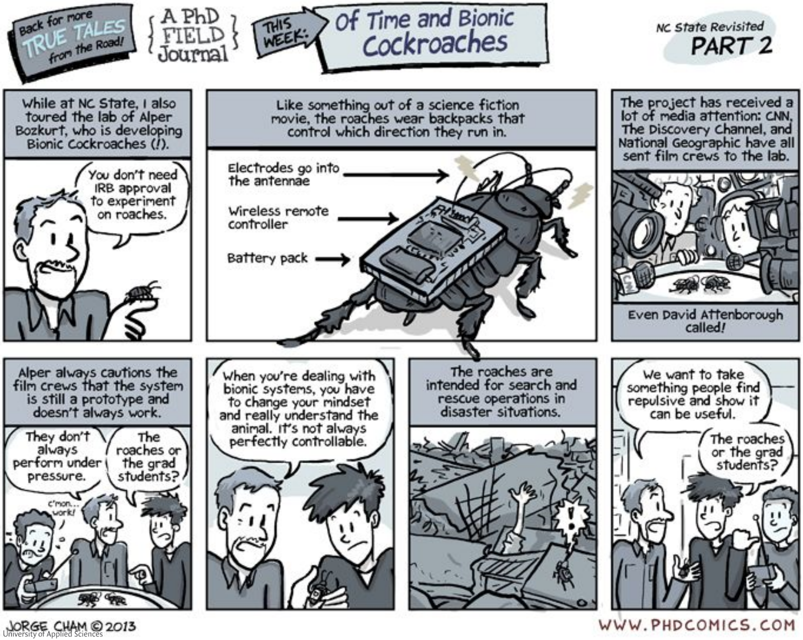



## Discrete Space Configuration



## Potential Fields




Back for more TRUE TALES from the Road!
A PhD FIELD Journal
THIS WEEK: Of Time and Bionic Cockroaches
NC State Revisited PART 2
While at NC State, I also toured the lab of Alper Bozkurt, who is developing Bionic Cockroaches (!).
You don't need IRB approval to experiment on roaches.
Like something out of a science fiction movie, the roaches wear backpacks that control which direction they run in.
Electrodes go into the antennae
Wireless remote controller
Battery pack
The project has received a lot of media attention: CNN, The Discovery Channel, and National Geographic have all sent film crews to the lab.
Even David Attenborough called!
Alper always cautions the film crews that the system is still a prototype and doesn't always work.
They don't always perform under pressure.
c'mon... work!
The roaches or the grad students?
When you're dealing with bionic systems, you have to change your mindset and really understand the animal. It's not always perfectly controllable.
The roaches are intended for search and rescue operations in disaster situations.
We want to take something people find repulsive and show it can be useful.
The roaches or the grad students?
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