Mobile Robotics

Prof. Dr.-Ing. Gavin Kane

Classical / Hierarchical Paradigm

- Using a Perfect World Model with a closed world assumption
- Focus on automated reasoning and knowledge representation
- 1970s

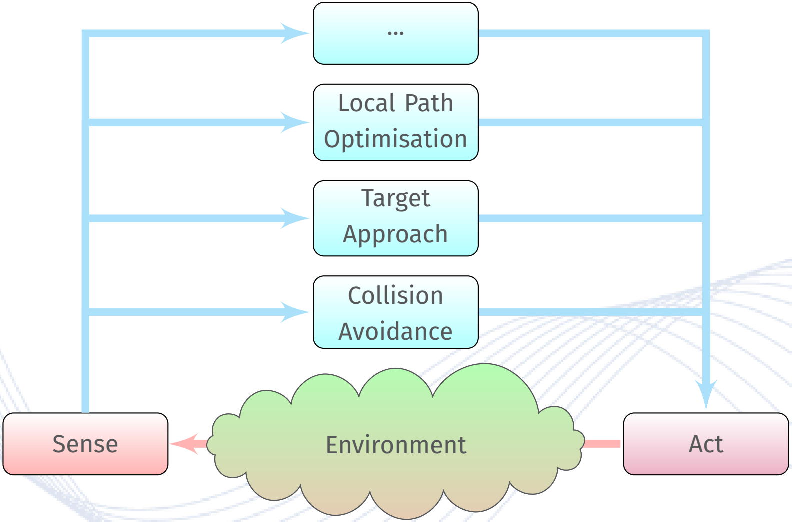
Reactive / Behavior-based Paradigm

- No model
- Hierarchy of Tasks, priority based, or additive ”forces”
- Early successes, but also limitations
- Investigate biological systems
- Also as basis for Swarm Intelligence

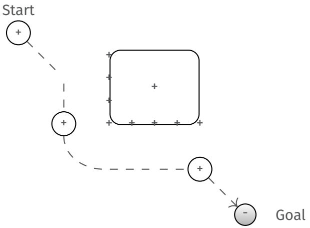
- Braitenberg Vehicles as example

- Robot is part of environment
- No memory required in Robot
- Minimal computing power required
- Robot only makes use of local knowledge, no global optimisation of behaviour

Reactive Paradigm Hierachy of Tasks



Potential Field Method



Potential Field

- Treat robot as particle acting under the influence of a potential field
- Robot travels along the derivative of the potential
- Field depends on obstacles, desired travel directions and targets
- Resulting field (vector) is given by the summation of primitive fields
- Strength of field may change with distance to obstacle/target

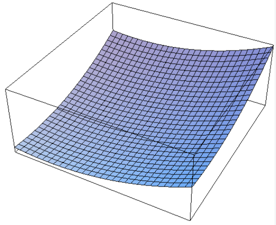
Potential Field Methods

Attractive/Repulsive Potential Field

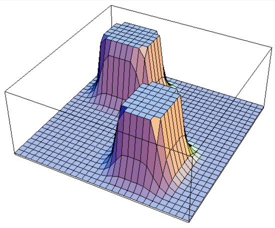
U_{att} is the "attractive" potential — move to the goal

U_{rep} is the "repulsive" potential — avoid obstacles

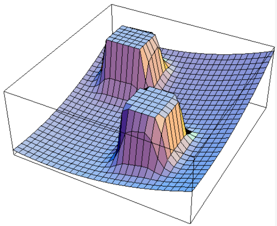
Attractive Field



Repulsive Field



Total Potential Function



University of Applied Sciences
HOCHSCHULE
EMDEN·LEER

Potential Field Methods

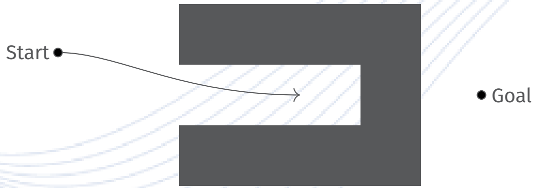
Gradient Descent

$$U(q) = U_{att} + U_{rep} \tag{1}$$

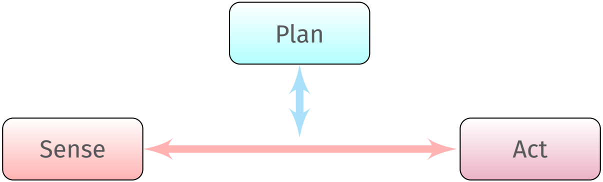
A simple way to get to the bottom of a potential

$$F(q) = -\nabla U(q) \tag{2}$$

A Critical Point is where $\nabla U(q) = 0$

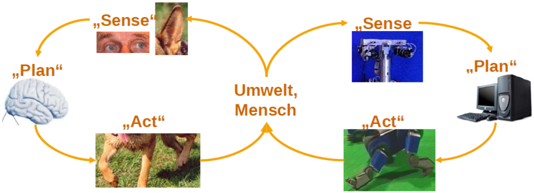


Hybrid Deliberative / Reactive Paradigm



Hybrid Paradigm

- Combines advantages of previous paradigms
- World model used for planning
- Closed loop, reactive control



Grafik: TU Darmstadt / Autonome Systeme

Hybrid Deliberative / Reactive Paradigm

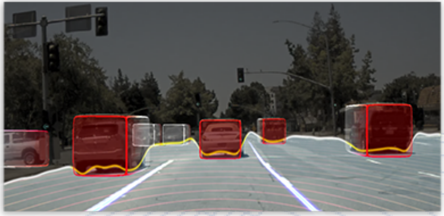
Advantages Disadvantages

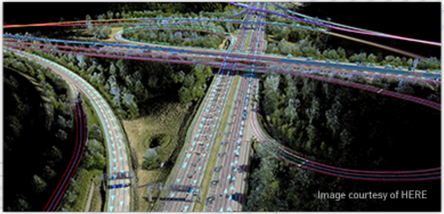
- All three levels work asynchronously and with different time scales and data representations.
- Advantages of the Architecture is the combination of the Planing (deliberate) and Execution (Reactive), and a combined performance of the execution.
- Disadvantage is the difficult coordination of all three levels of the model, and their different data models and time scales.
- Many different variations and implementations of the architectures exist. As an example, it is possible to include Artificial Intelligence in one or more levels of the system, neural networks in another, direct PID controls or intessive algorithms in another levels for the best combination of time scales and optimisations that the hardware allows.

Motion Models

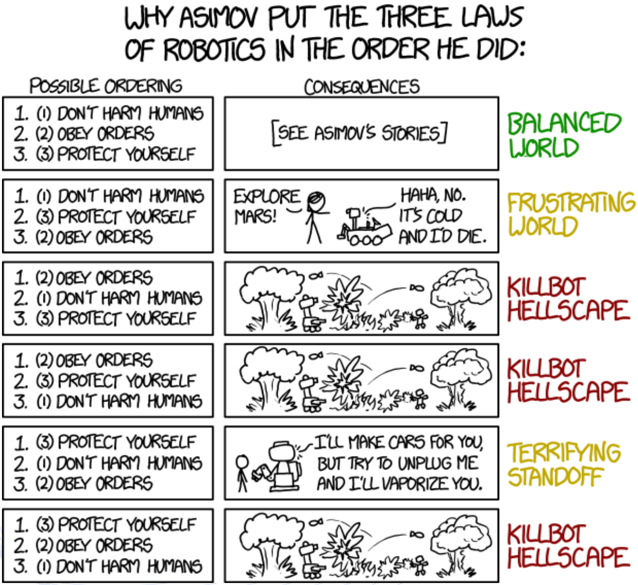
Industry Example Applied Paradigm

https://www.youtube.com/watch?v=URmxzxYlmtg





Source: NVidia


WHY ASIMOV PUT THE THREE LAWS OF ROBOTICS IN THE ORDER HE DID:
POSSIBLE ORDERING
CONSEQUENCES
1. (1) DON'T HARM HUMANS
2. (2) OBEY ORDERS
3. (3) PROTECT YOURSELF
[SEE ASIMOV'S STORIES]
BALANCED WORLD
1. (1) DON'T HARM HUMANS
2. (3) PROTECT YOURSELF
3. (2) OBEY ORDERS
EXPLORE MARS!
HAHA, NO. IT'S COLD AND I'D DIE.
FRUSTRATING WORLD
1. (2) OBEY ORDERS
2. (1) DON'T HARM HUMANS
3. (3) PROTECT YOURSELF
KILLBOT HELLSCAPE
1. (2) OBEY ORDERS
2. (3) PROTECT YOURSELF
3. (1) DON'T HARM HUMANS
KILLBOT HELLSCAPE
1. (3) PROTECT YOURSELF
2. (1) DON'T HARM HUMANS
3. (2) OBEY ORDERS
I'LL MAKE CARS FOR YOU, BUT TRY TO UNPLUG ME AND I'LL VAPORIZE YOU.
TERRIFYING STANDOFF
1. (3) PROTECT YOURSELF
2. (2) OBEY ORDERS
3. (1) DON'T HARM HUMANS
KILLBOT HELLSCAPE