Physical Path Planning using a Network of Learning Sensors

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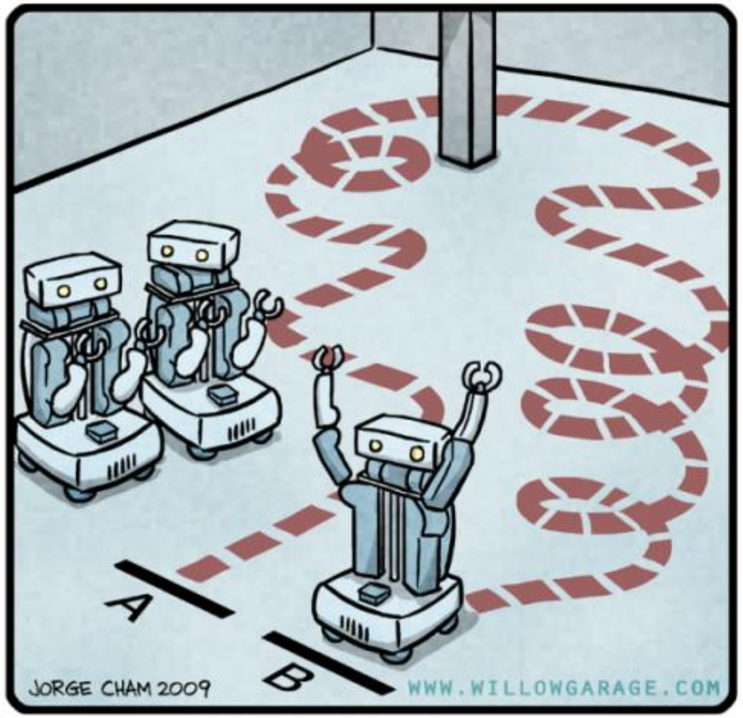
Path Planning

- Finding the most optimal route for a mobile robot that connects its current location to a desired destination



"HIS PATH-PLANNING MAY BE SUB-OPTIMAL, BUT IT'S GOT FLAIR."

Source: willowgarage.com

Approaches to Path Planning

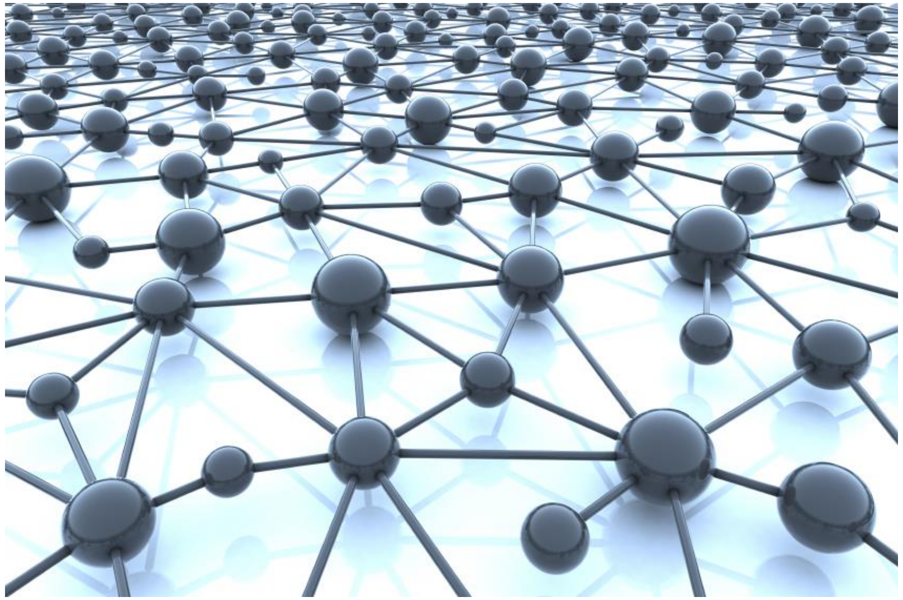
- Path planning can be done by
  - Single or multiple robots
  - Network of sensors (aka **Physical path planning**)
  - A combination of both
- Types of path planning include:
  - **Local** - moving forward and avoiding obstacles
  - **Global** - finding the shortest path

Proposed Paper

- C. M. Vigorito**. Distributed path planning for mobile robots using a swarm of interacting reinforcement learners**. In Proceedings of the 6th international joint conference on Autonomous agents and multi-agent systems , Honolulu, May 2007
- A global physical path planning algorithm using a Swarm of Interacting Reinforcement Learners (SWIRLs)

Distance Vector Routing

- A global optimal solution to finding the minimum cost path
- Nodes keep a record of the minimum costs in the form of a **Distance Vector (DV)**
- DV here is an array of distances to other nodes in the network
- DV estimates are broadcasted and updated by each node through internal communications



Source: openterra.com

Distance Vector Routing

- Update rule:

$$D(x,z) = \min_{y \in N(x)} d(x,y) + D(y,z)$$

- $D(x,z) \rightarrow$ the minimum cost from x to z
- $D(y,z) \rightarrow$ the minimum cost from y to z
- $d(x,y) \rightarrow$ direct cost between x and y
- $N(x) \rightarrow$ all x's communicable neighbours

Reinforcement learning

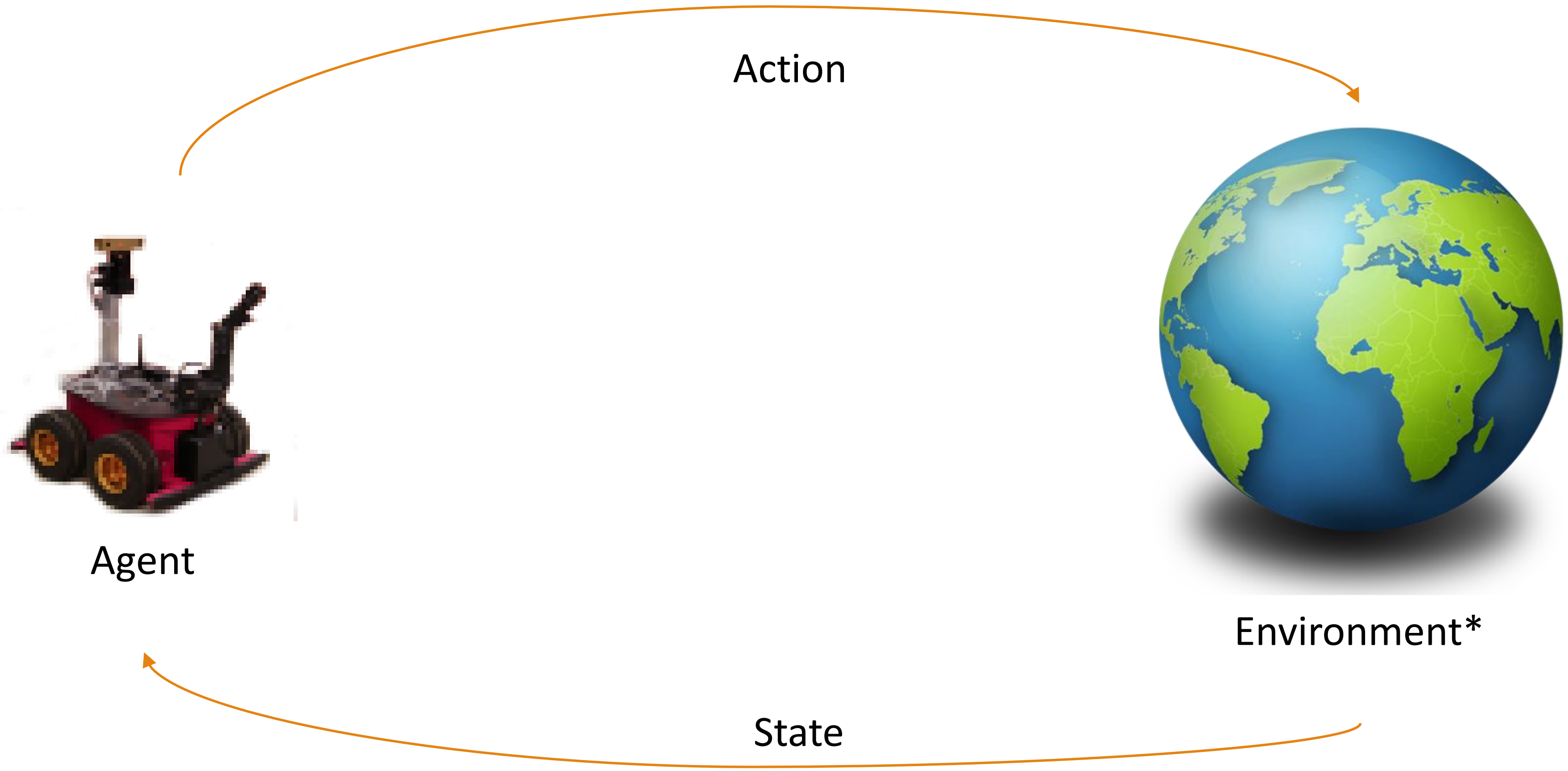
Action

Agent

Environment*

*source: blog.sbtjapan.com

Reinforcement learning



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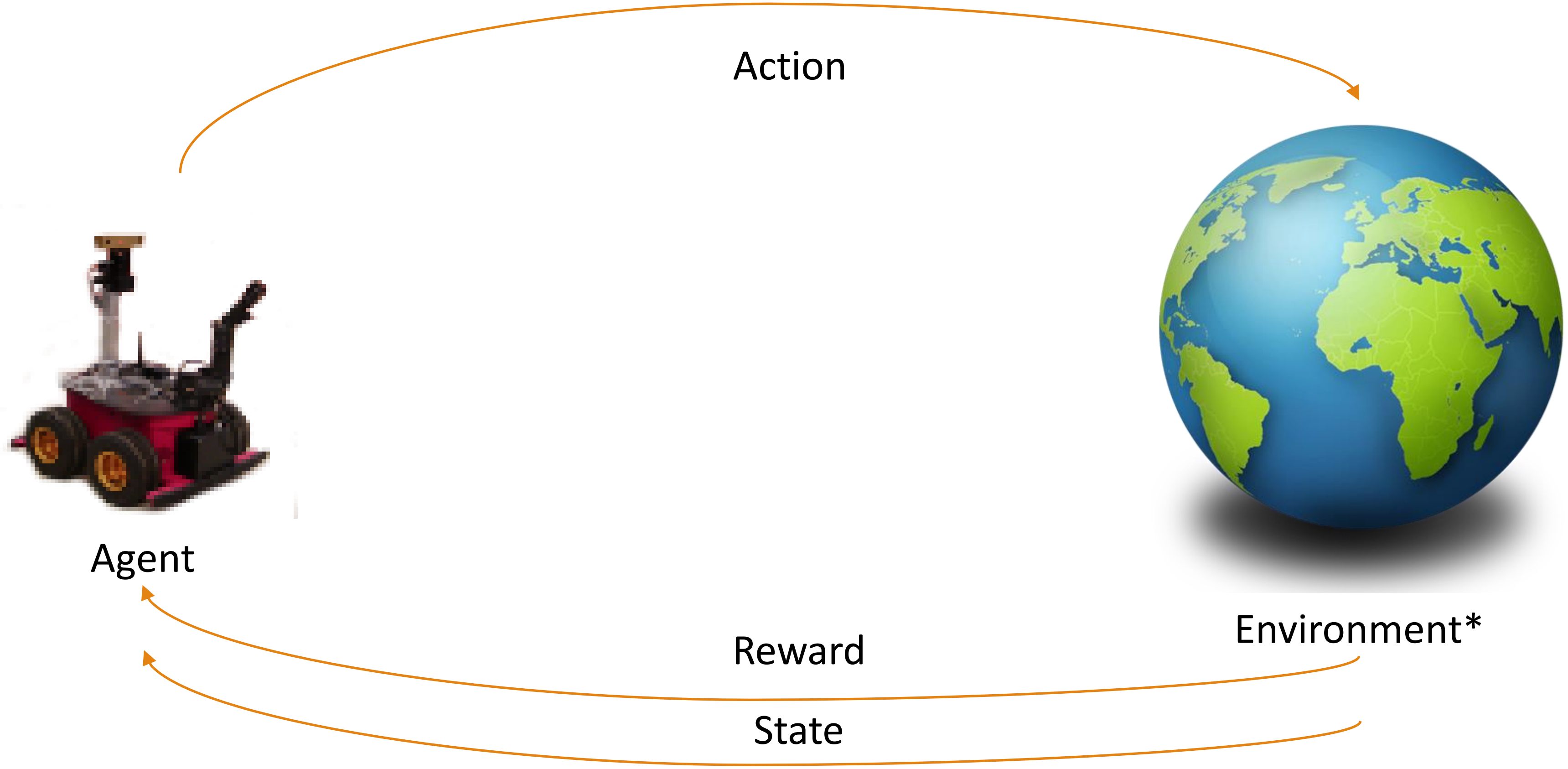
Reinforcement learning



*source: blog.sbtjapan.com

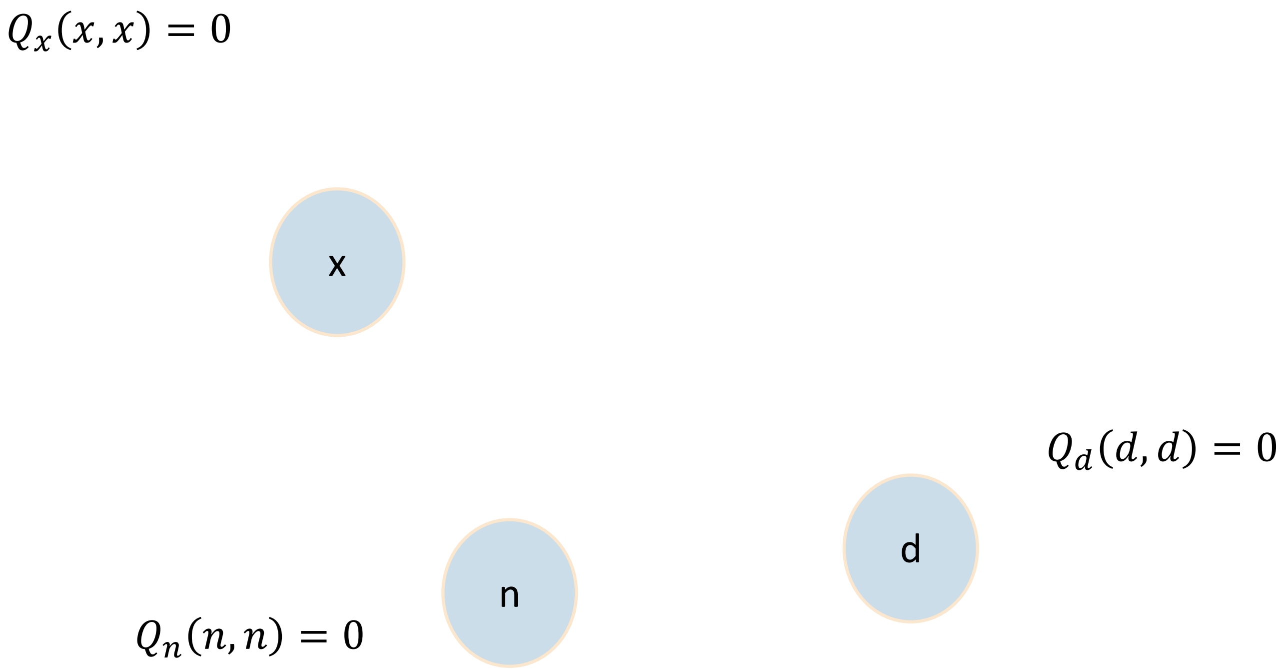
SWIRLs

- **Assumptions:**
  - Robots and sensors can acquire each other’s locations and distances
  - Wireless communication
  - Robots have local path planners
  - Maximum speed of robots is the same
  - There exists at least one path between any given pair of sensors

SWIRLs

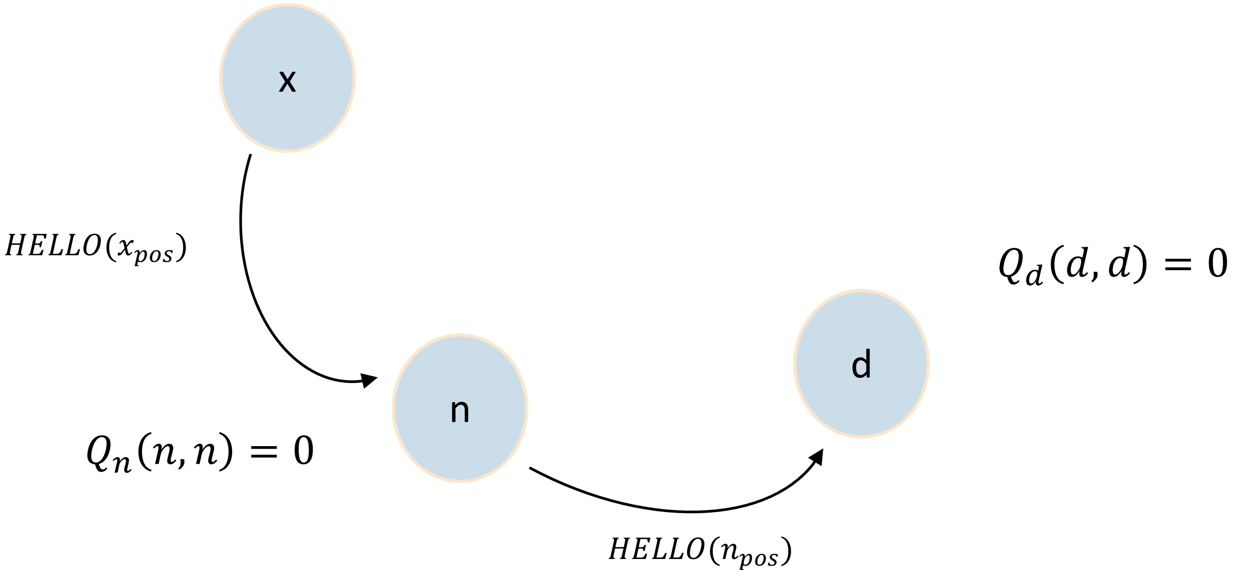
- **Algorithm**
  - *Initialization stage:* sensors communicate to identify their neighbors
  - *Estimate stage:* sensors acquire distance information to potential destinations
  - *Query stage:* a robot asks for a path and the closest sensor provides it

Initialization Stage



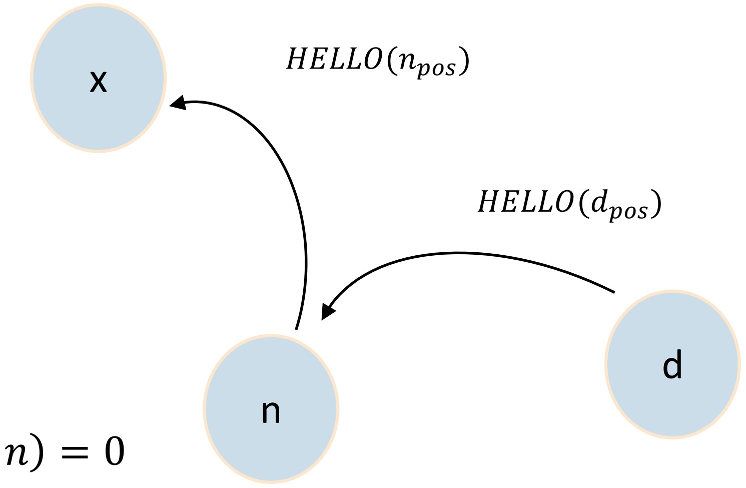
Initialization Stage

$Q_x(x, x) = 0$



Initialization Stage

$Q_x(x, x) = 0$



$Q_d(d, d) = 0$

$Q_d(n, n) = Est._n$

$n \rightarrow N(d)$

$Q_n(n, n) = 0$

$Q_n(x, x) = Est._x$

$x \rightarrow N(n)$

Initialization Stage

$$Q_x(x,x) = 0$$

$$Q_x(n,n) = Est._n$$

$$n \rightarrow N(x)$$

x

$$Q_d(d,d) = 0$$

d

$$Q_d(n,n) = Est._n$$

n

$$N(d) = [n]$$

$$Q_n(n,n) = 0$$

$$Q_n(x,x) = Est._x$$

$$Q_n(d,d) = Est._d$$

$$d \rightarrow N(n)$$

Initialization Stage

$Q_x(x,x) = 0$

$Q_x(n,n) = Est._n$

$N(x) = [n]$

x

$Q_d(d,d) = 0$

d

$Q_d(n,n) = Est._n$

n

$N(d) = [n]$

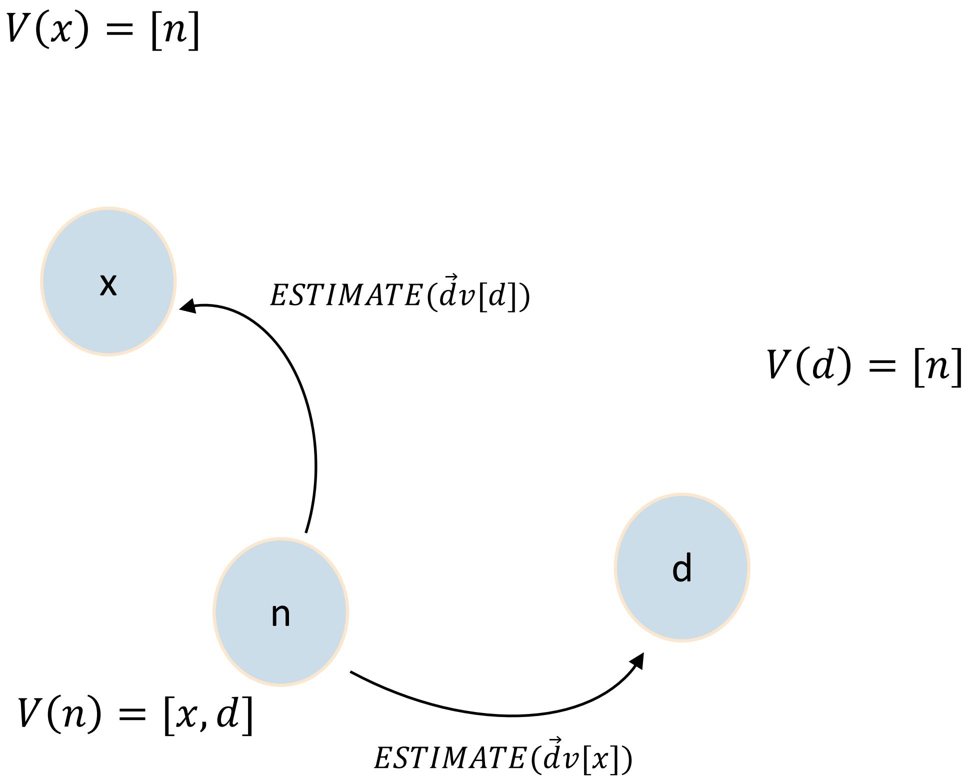
$Q_n(n,n) = 0$

$Q_n(x,x) = Est._x$

$Q_n(d,d) = Est._d$

$N(n) = [x,d]$

Estimate Stage



Estimate Stage

$$V(x) = [n]$$
$$Q_n^*(d,d) + Q_x(n,n) \to Q_x(n,d)$$
$$d \to V(x)$$

x

$$V(d) = [n]$$
$$Q_n(x,x) + Q_d(n,n) \to Q_d(n,x)$$
$$x \to V(d)$$

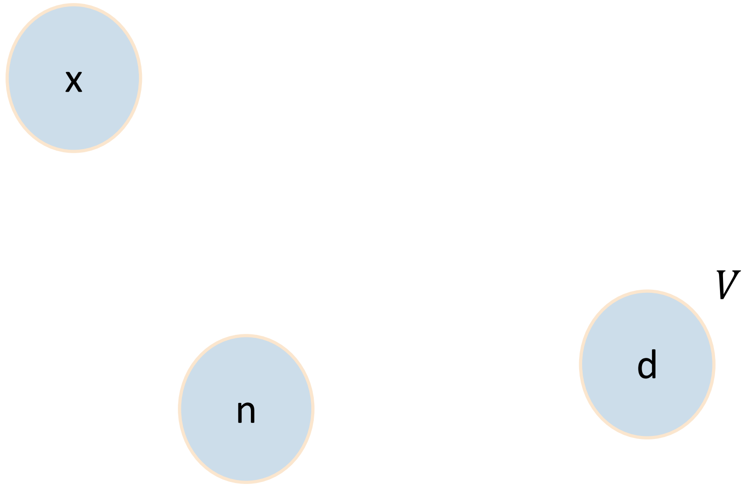
d

n

$$V(n) = [x,d]$$

Estimate Stage

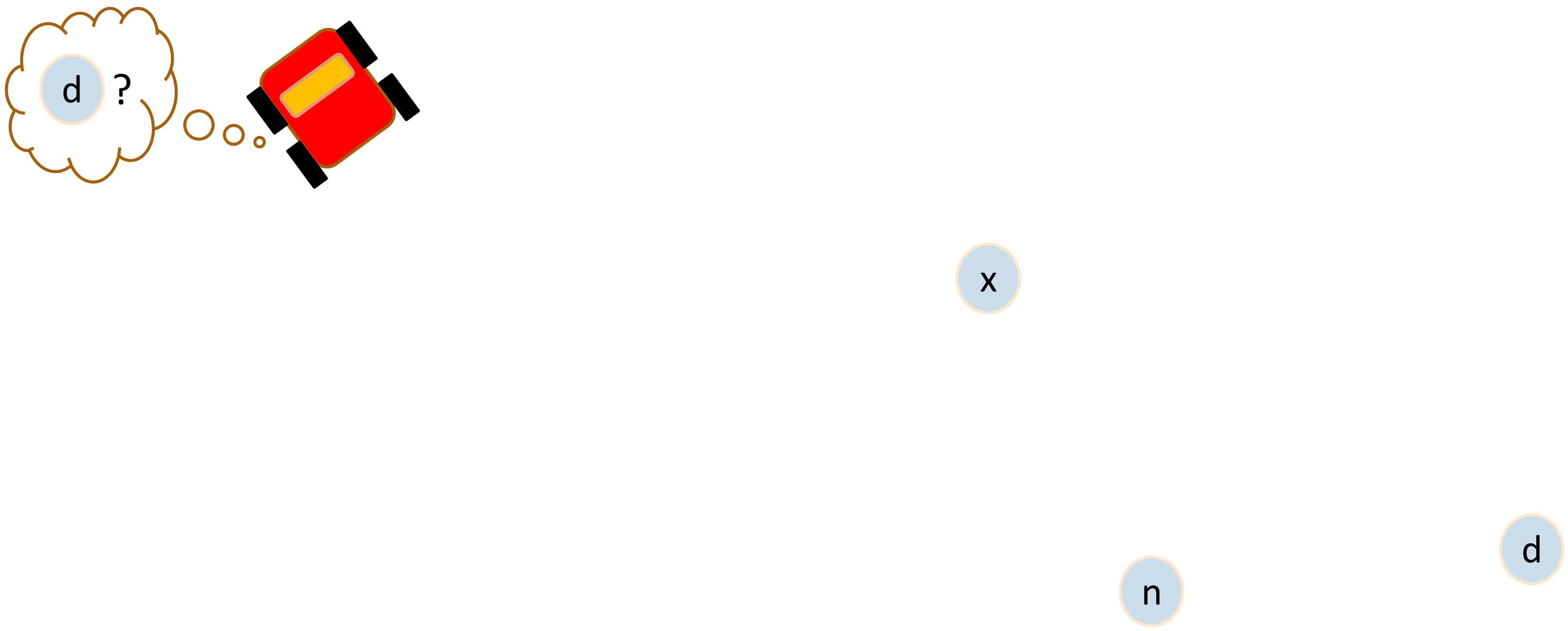
$V(x) = [n, d]$



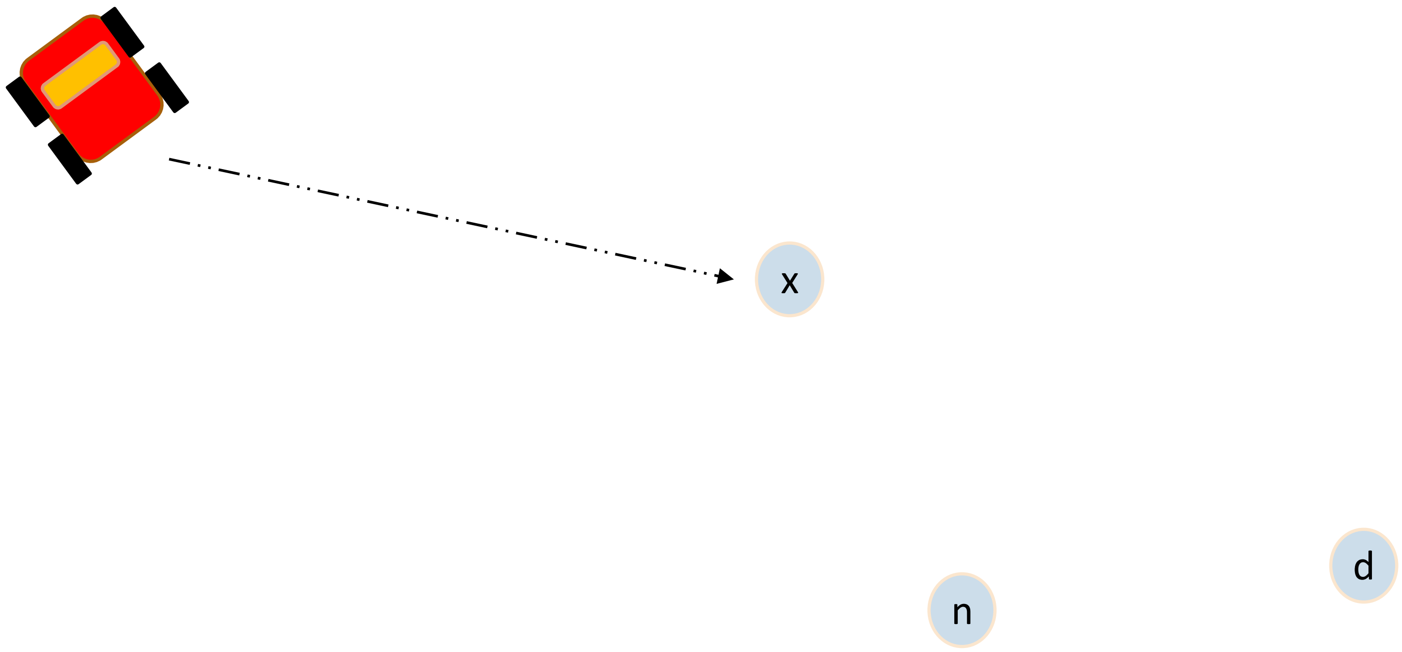
$V(d) = [n, x]$

$V(n) = [x, d]$

Query stage



Query stage



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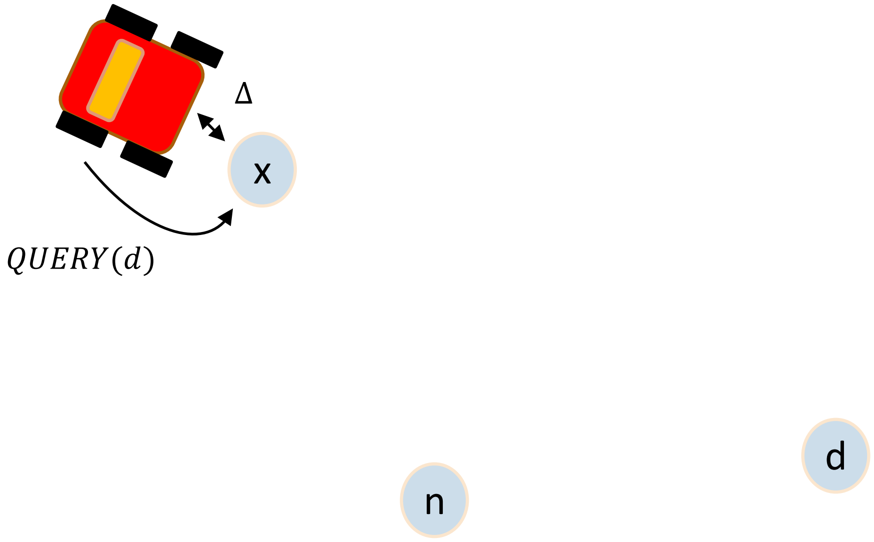

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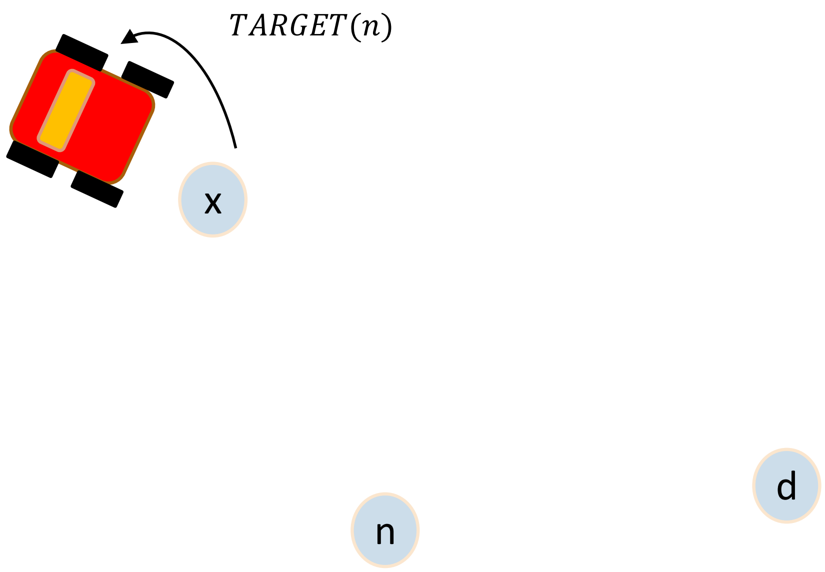

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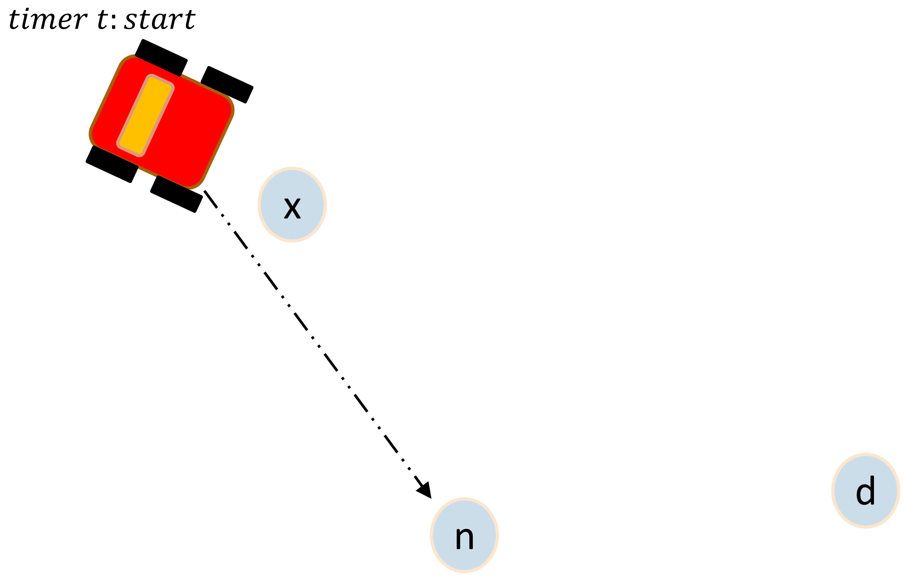

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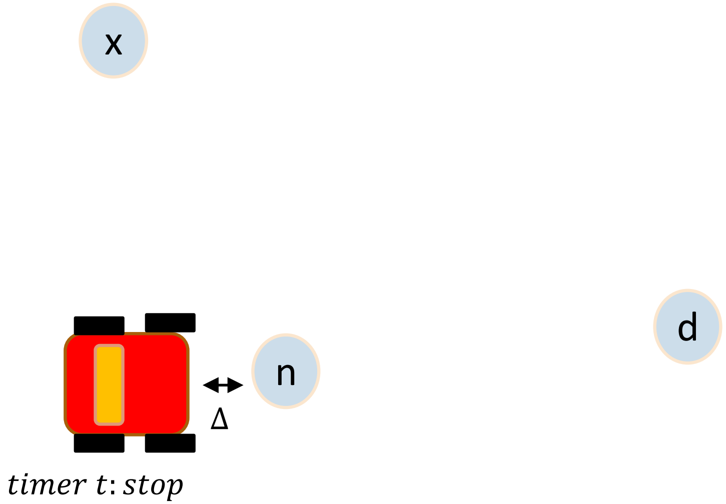
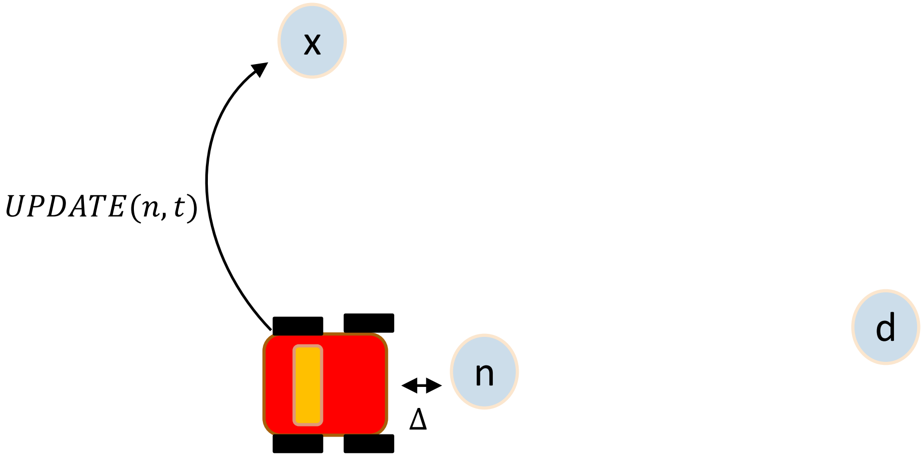
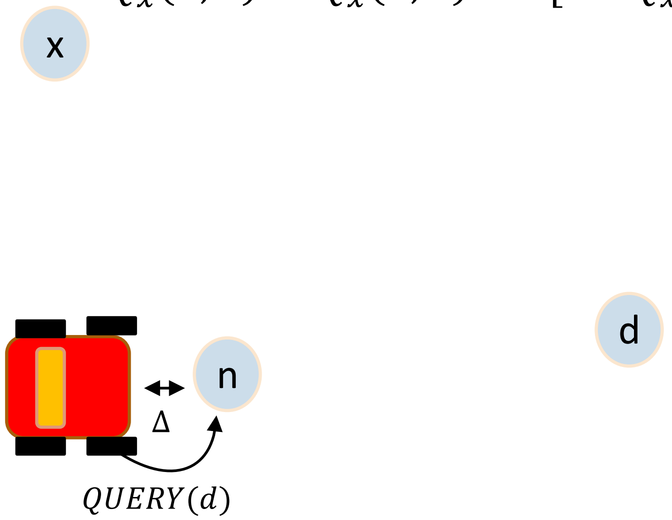


Query stage

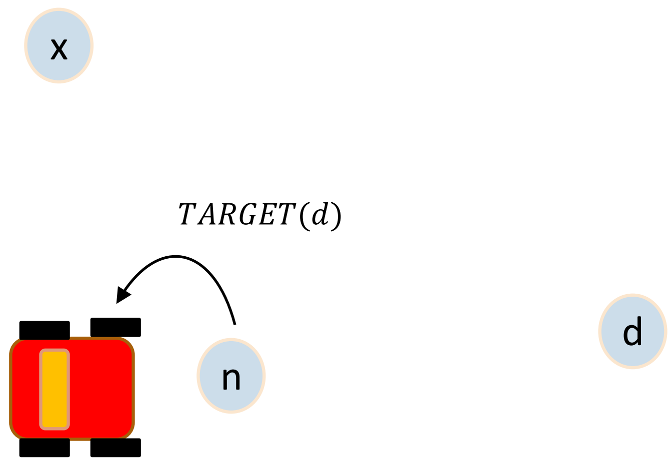


Query stage

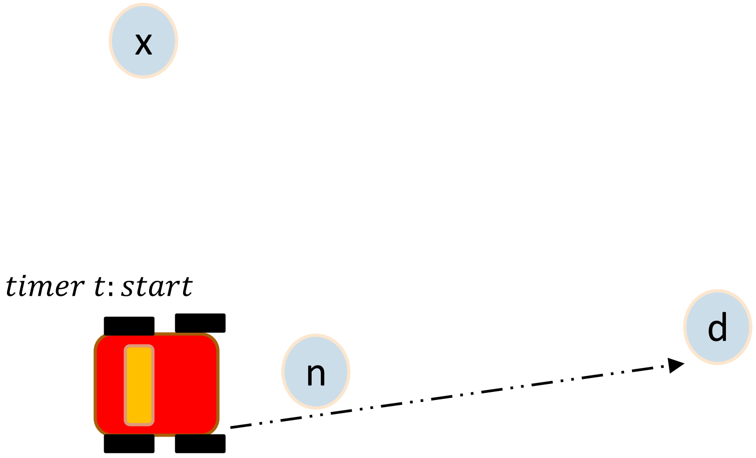
$$Q_x(n,d) \leftarrow Q_x(n,d) + \alpha[t - Q_x(n,n)]$$



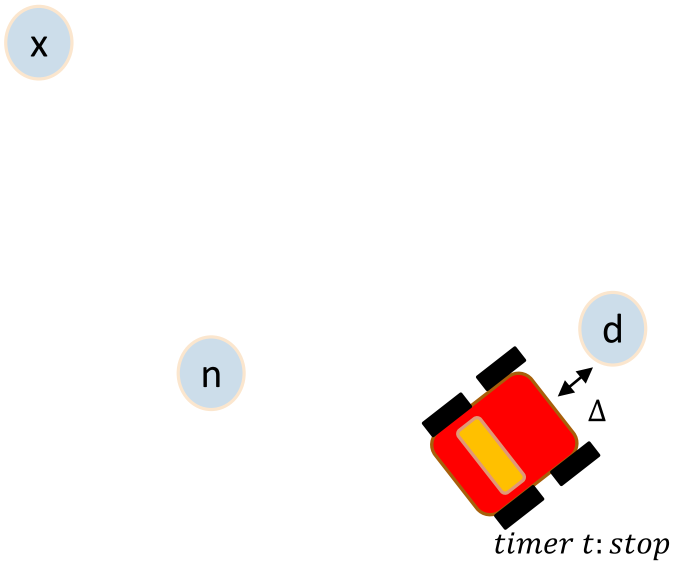
Query stage



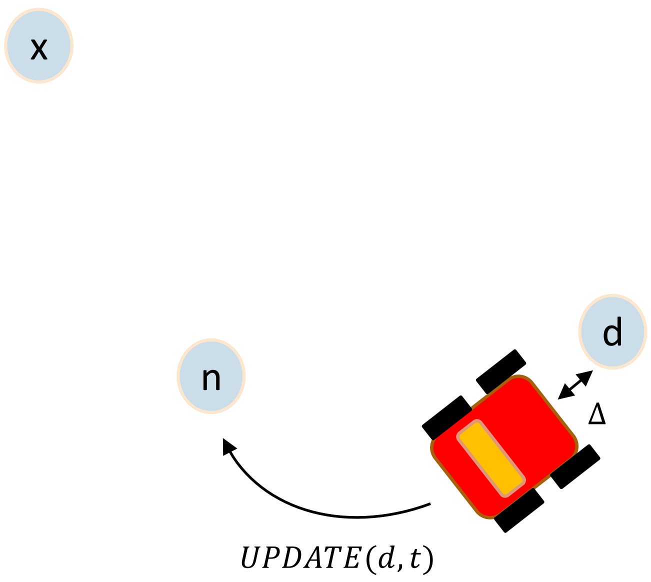
Query stage



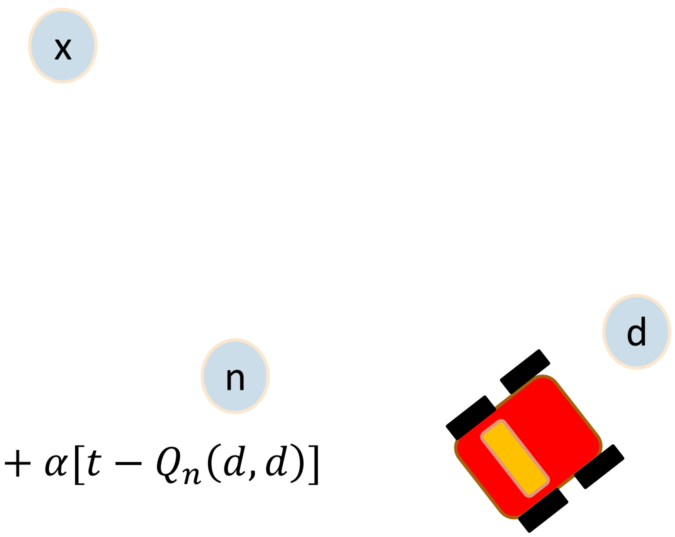
Query stage



Query stage



Query stage



$$Q_n(d,d) \leftarrow Q_n(d,d) + \alpha[t - Q_n(d,d)]$$

Conclusion

- SWIRLs network exploits a concurrent architecture and learning to perform path planning
- SWIRLs is suitable for unstructured and unknown environments
- **Potential extensions**
  - Add fault tolerance
  - Solve unreachable nodes problem
  - Assume varying speeds for robots

Proposed Implementation

- **Approach 1:**
  - Implement each sensor as one thread
  - Compare the performance with sequential approach
- **Challenges:**
  - Multiple communications between sensors and robots
  - Ensure fairness among inquiring parties
  - Possibility of starvation or deadlock

Proposed Implementation

- **Approach 2:**
  - Each sensor is multi-threaded to handle communication
  - Measure how increasing the number of threads impacts the overall performance
- **Challenges:**
  - Shared memory access
  - Fairness problem
  - Possibility of starvation or deadlock