

The ALADDIN Project

Autonomous Learning Agents for Decentralised Data and Information Networks

A Successful University / Industrial Collaboration

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Autonomous Learning Agents for Decentralised Data and Information Networks

- Funded through a BAE Systems and Engineering and Physical Sciences Research Council (EPSRC) strategic partnership.
- £5M multidisciplinary research project, which started in October 2005.
- Involves the Universities of Southampton, Oxford and Bristol, and Imperial College London involving over 30 researchers.
 - Prof. Nick Jennings (University of Southampton)
 - Simon Case (BAE Systems)



Autonomous Learning Agents for Decentralised Data and Information Networks

“ALADDIN is one of the most successful Industry and University collaborations, with great potential for application”

Professor Andrew Baird, Director Defence Technology and Innovation Centre and Chair of the ALADDIN Independent Steering Group.

Autonomous Learning Agents for Decentralised Data and Information Networks

- Over 80 academic papers in top ranked international conferences (best paper awards and nominations).
- Won international research competitions.
- Set academic research agenda through international workshops.
- Won the British Computer Society's Distinguished Dissertation Award in both 2007 and 2008.



ATDM

ATSN OptMAS



autonomous learning agents for decentralised data and information networks

Autonomous Learning Agents for Decentralised Data and Information Networks

- 4 patents applications.
- BAE Systems Chairman's Award for Innovation and Implementation.
- The Engineer award for Best Aerospace and Defence Project in 2009 – a “stunning collaboration”.
- Achieved real technology transfer and exploitation.



autonomous learning agents for decentralised data and information networks

Autonomous Learning Agents for Decentralised Data and Information Networks

- **Develop techniques, methods and architectures for modelling, designing & building decentralised systems that can bring together information from heterogeneous sources to take informed action.**
- **Achieve these objectives in environments in which:**
 - Control is distributed.
 - Uncertainty, ambiguity, and bias are endemic.
 - Multiple (self-interested) stakeholders with different aims and objectives are present
 - Resources are limited and continually vary during system's operation.
 - Timeliness of action is important

Demonstrating and evaluating these novel approaches in the domain of disaster response



Decentralised
Coordination

Resource
Allocation

Sensing and Data
Fusion



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We have developed, extended and applied a wide range of algorithms and mechanisms

Single Agents

Bayesian Kalman filter

Gaussian processes

Multi-armed bandits

Random neural networks

Generalised covariance union

Recursive adaptive forgetting

Auction mechanisms

Multiple Agents

Probability collectives

Selective Fusion

Mechanism Design

Iterative algorithms

Coalitional bargaining

Decentralised Bayesian Collaboration

Max-sum algorithm

Random neural networks

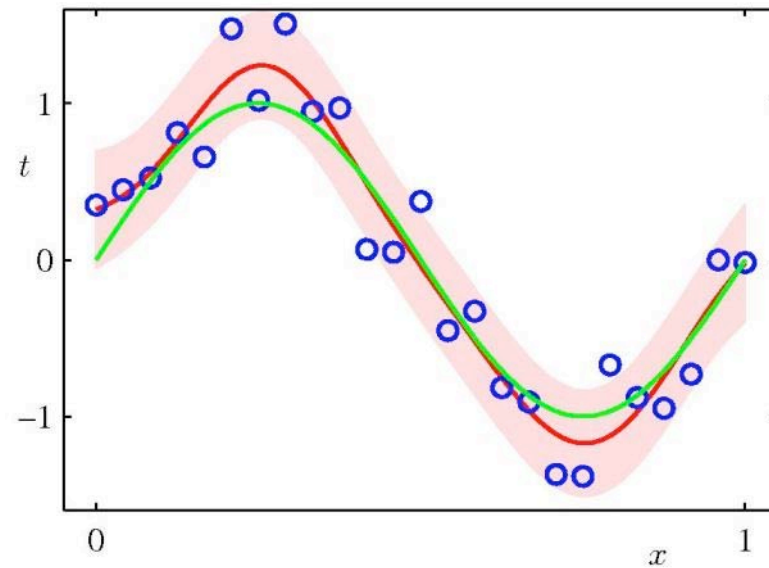
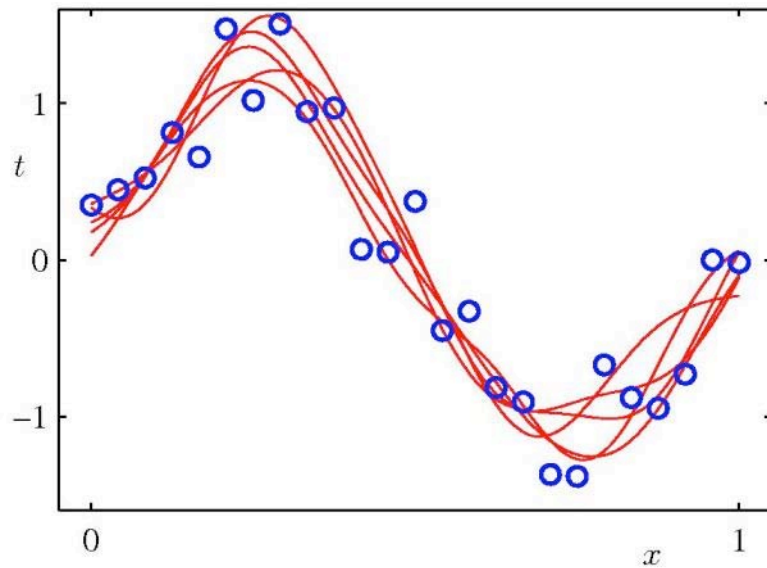
Multi-unit auctions

Coalition formation



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We developed a computationally efficient iterative formulation of a Gaussian processes to represent and reason about uncertain sensor data



We developed a computationally efficient iterative formulation of a Gaussian processes to represent and reason about uncertain sensor data

- Represent complex spatial-temporal correlations
 - Described by parameterised covariance functions
 - Represent specific domain knowledge
- Bayesian Monte Carlo
 - Marginalising over hyperparameters
 - More complex models and represent model uncertainty
- Iterative updating
 - Iteratively compute this matrix as new data arrive
 - Exploit previous computation for streaming data



Sensor Type

- Air pressure
- Air temperature
- Max wave height
- Mean wave height
- Sea temperature
- Tide height**
- Visibility
- Wave periodicity
- Wind direction
- Wind gust speed
- Wind speed

Dataset

Missing data

Gaussian Process Prediction

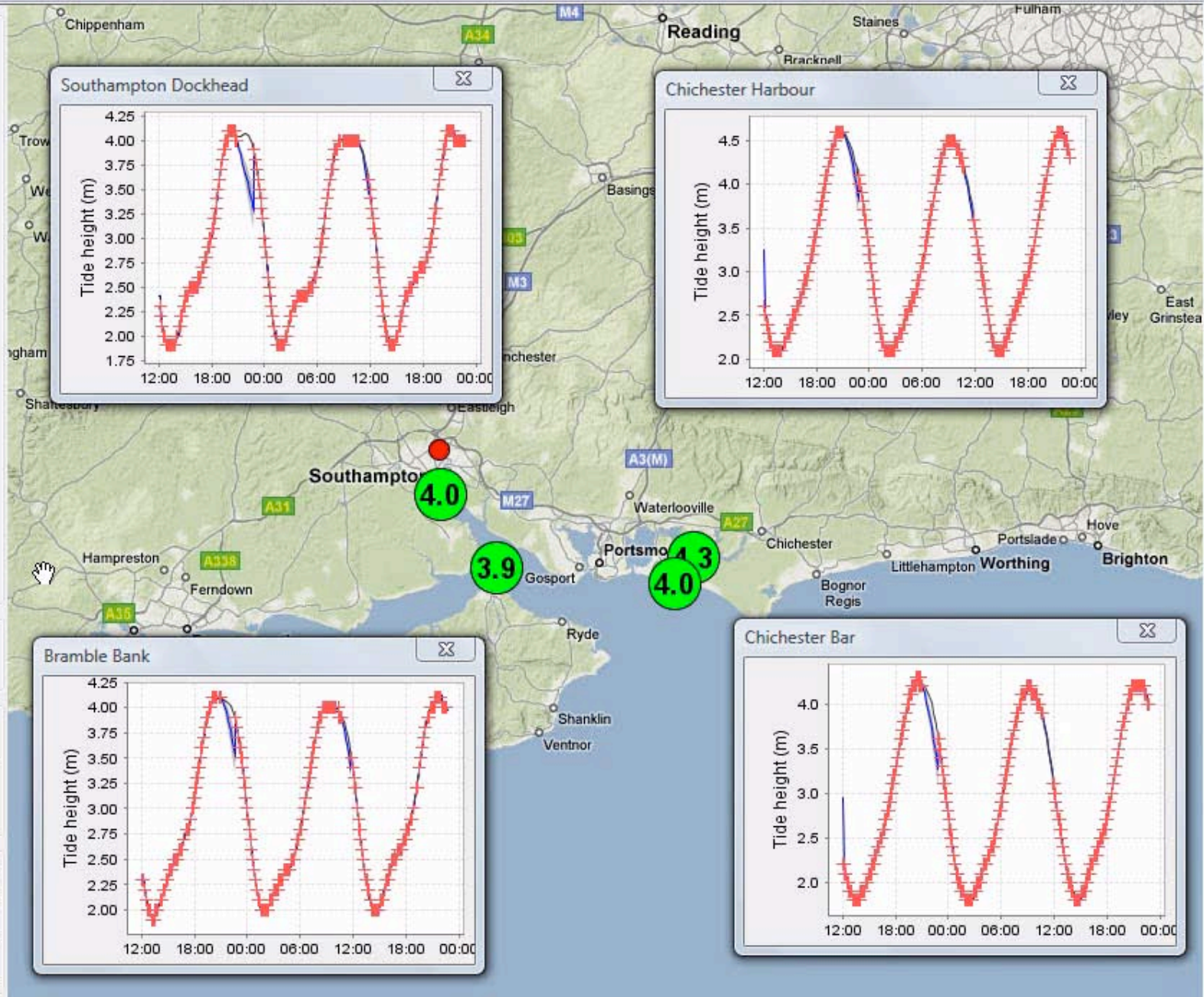
- True Value
- Independent GP Prediction
- Dependent GP Prediction

Data Playback

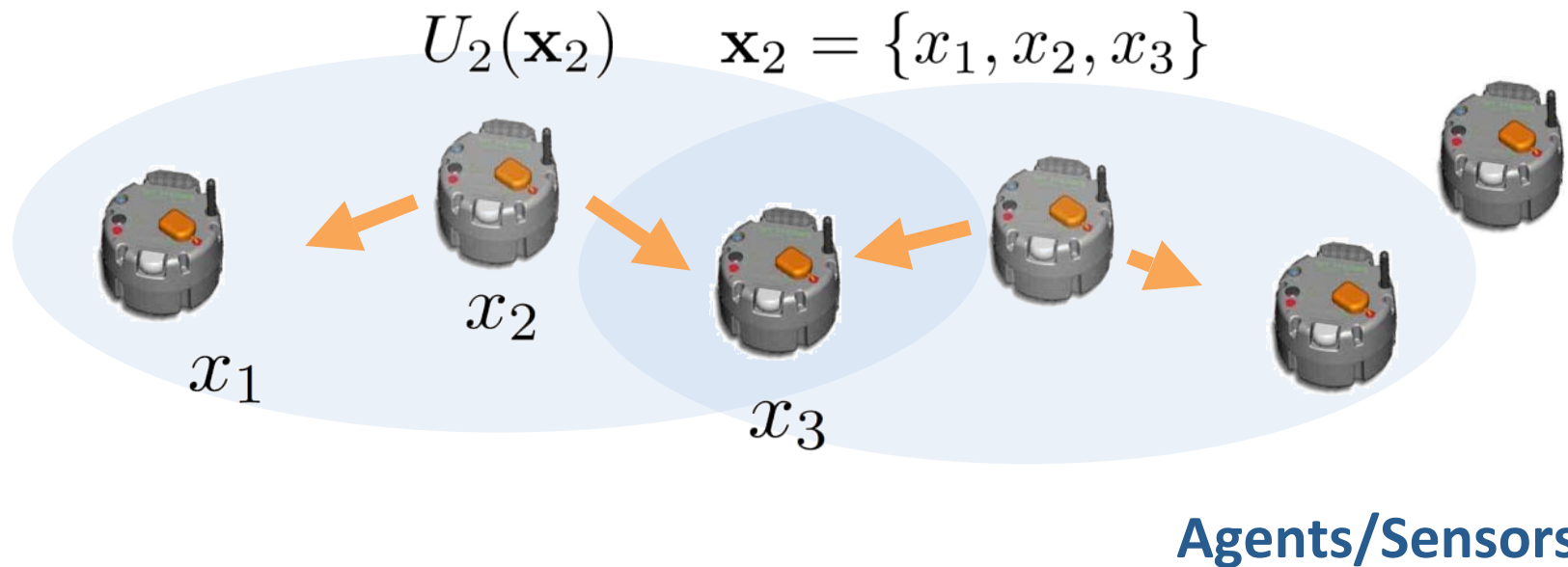
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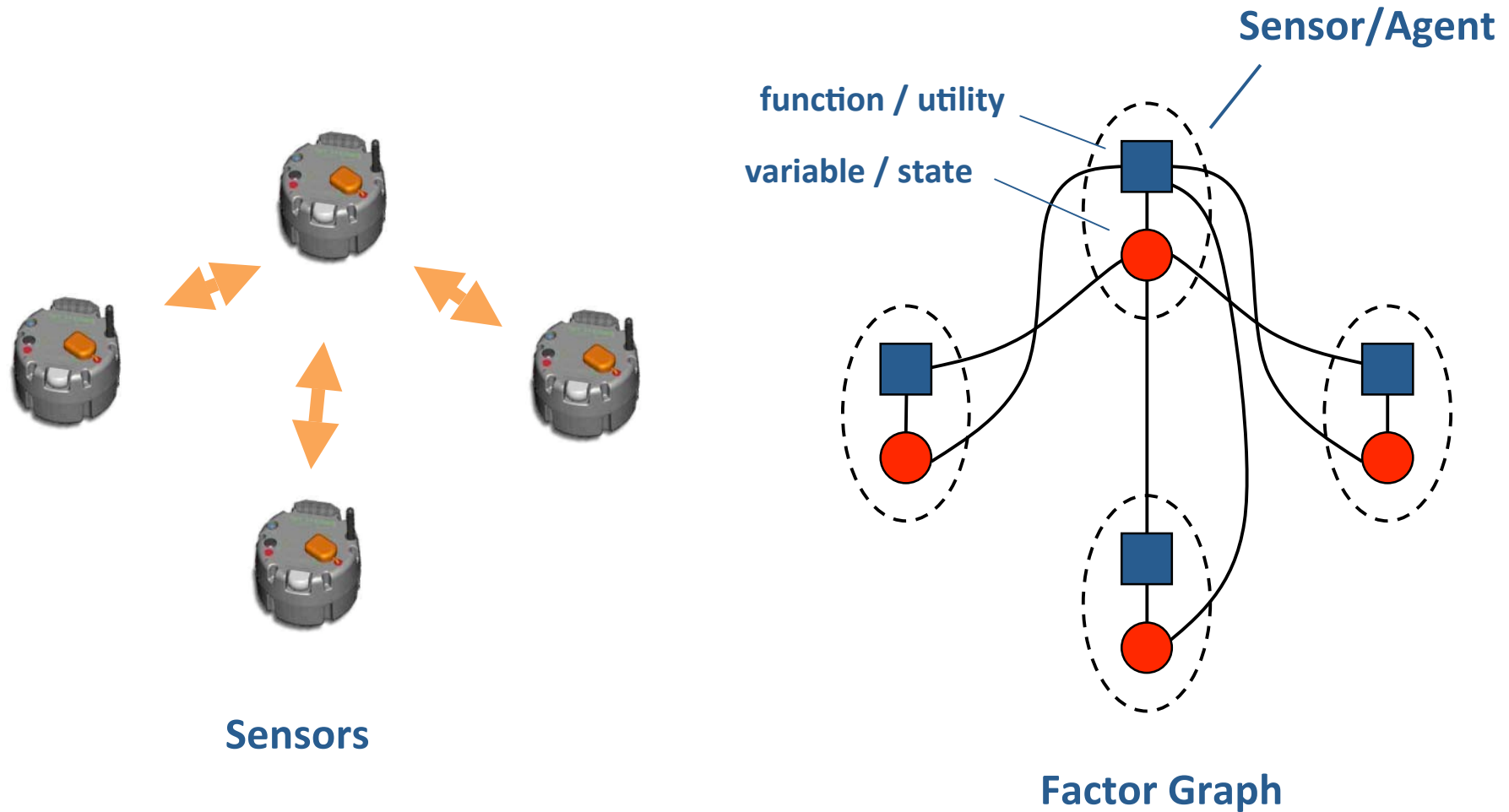
We developed efficient decentralised coordination algorithms based upon the max-sum algorithm



Maximise Social Welfare: $\arg \max_{\mathbf{x}} \sum_{m=1}^M U_m(\mathbf{x}_m)$



We construct a factor graph from the underlying sensor utility interactions



We have developed a number of extensions to the foundational max-sum algorithm

Continuous action spaces

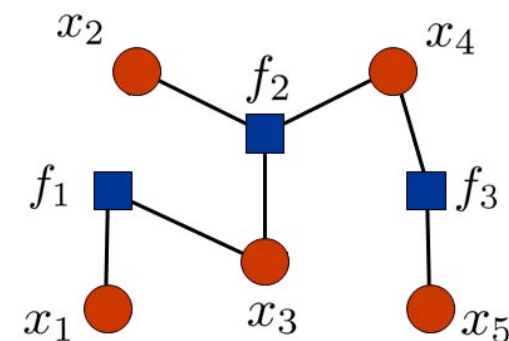
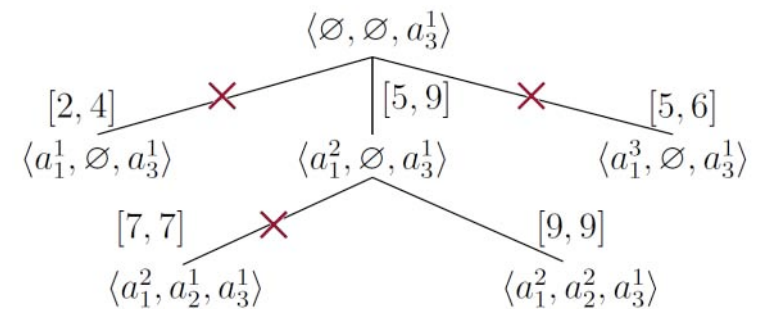
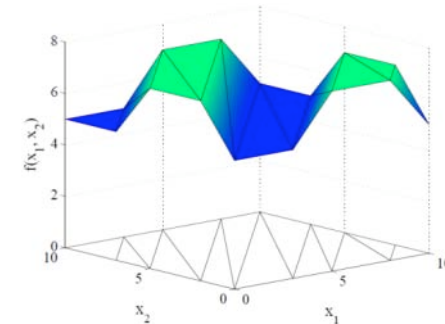
- Piece-wise linear utility functions

Computational efficiency

- Branch and bound to improve message calculation efficiency

Bounded approximate solutions

- Prune factor graph to a tree
- Calculate bound from the optimal solution



Map



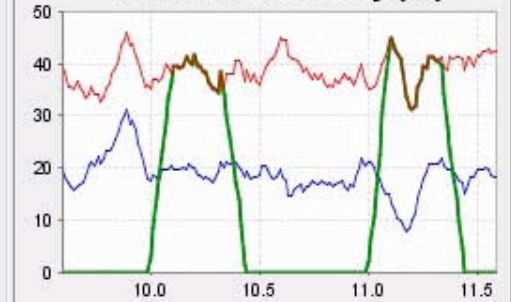
Control Panel

New Reset Coordinate Learning...

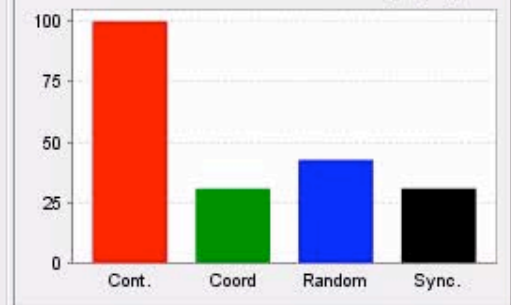
Metrics

Efficiency Detection

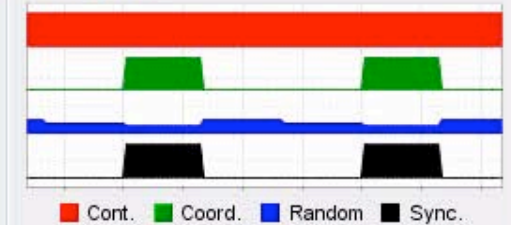
Network Efficiency (%)



Normalised Efficiency (%)



Active Sensors



Algorithms

- None
- Continuously Powered Sensors
- Coordinated Sensors
- Random Sensors
- Synchronised Sensors

ALADDIN has achieved real and significant technology transfer and exploitation of fundamental research

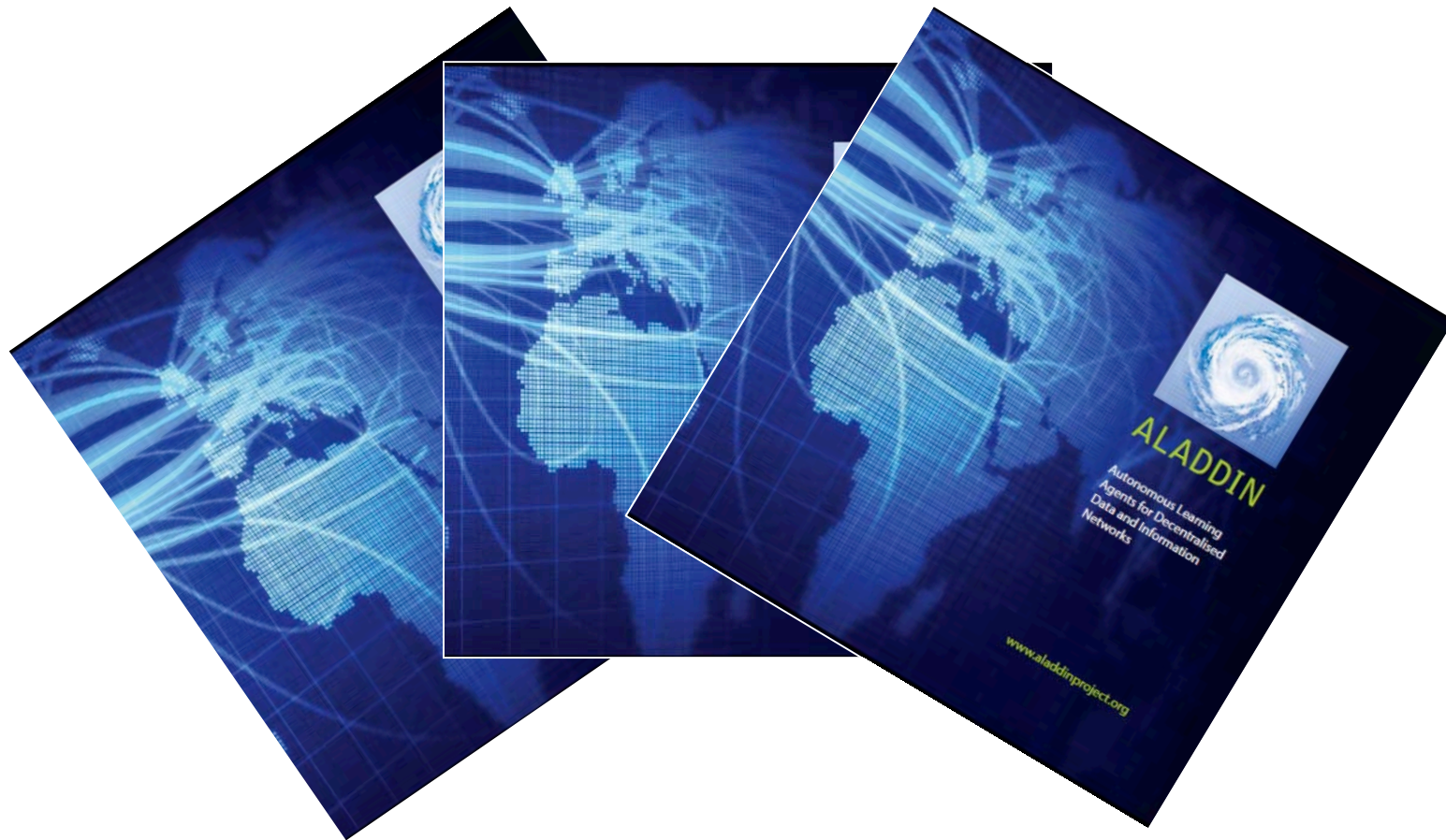
- Situational awareness for port operators
- Sensor fault recovery for UAV
- Coordination algorithms for Force TEWA demonstrated within BAE System's CMS-1 Combat Management System
- Agent-based modelling of reverse supply chains



ALADDIN has achieved real and significant technology transfer and exploitation of fundamental research

- Long term collaborative relationships
- Focused demonstration scenarios requiring interdisciplinary input
- Two way secondments
 - Industry to Academia / Academia to Industry
- Full time industrialists focused on technology pull-through and exploitation





www.aladdinproject.org

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