Modelling Real-World Complex Systems

Representing Uncertainty

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My Background

Study:
- PhD student – Centre for Computational Intelligence, De Montfort University, Leicester

Research interests:
- Application of Computational Intelligence techniques to real-world problems
- Fuzzy modelling of complex systems
Research Objective

The aim of the research was to:

- Improve inventory planning in a supply chain using Computational Intelligence techniques

The work was part of a larger Technology Strategy Board funded project concerned with using Computational Intelligence techniques to improve demand forecasting in a supply chain.
Inventory Planning

Inventory planning involves making decisions about how much stock to hold at each node of a supply chain.

This is difficult due to the uncertain nature of supply chain operation.
Inventory Planning

Poor management of inventory results in:

**Stock outs** - Inability to satisfy demand. Can lead to lost sales, orders, or customers.

**Carry over** - Holding some stock may be advantageous, holding too much incurs unnecessary cost.

There needs to be a trade off.
Fuzzy Sets

Fuzzy systems are used where there is:
- Vagueness
- Uncertainty
- Error/omissions

Fuzzy supply chain variables could represent:
- Demand forecast
- Inventory levels/costs
- Transport distances/times/costs
Crisp Sets

In crisp sets small changes in input can result in large changes in classification.

This is counter to the way in which humans describe objects.
Fuzzy Sets

Fuzzy sets allow an element to belong to one or more sets to a varying degree.

Degree of membership is **not** a probability.
Fuzzy Sets

Provides a gradual change in output as input alters.

Once sets have been created fuzziness is limited.
Interval Type-2 Fuzzy Sets

The degree of membership is often uncertain.

Type-2 Fuzzy sets add an extra degree of uncertainty.

Two main types:
- Interval
- Generalised
Generalised Type-2 Fuzzy Sets

Type-2 systems have been shown to work better in environments with a lot of uncertainty.

Allows computing with words, and group expert modelling.

Generalised type-2 has been prohibitively complex until recently.
The Model

The fuzzy model allows us to use vague and uncertain data to calculate the cost of a proposed solution.

An optimisation algorithm uses the model to search for good inventory plans.
Experiments

Phase 1
- Interval type-2 fuzzy model.

Phase 2
- Optimisation methods and configurations.

Phase 3
- Large-scale real-world scenario.
Results

Phase 1
- On simpler problems (Search space $6^{90} \& 6^{288}$) the system found solutions very close to the ideal solution (1.1% & 1.3% from ideal)

Phase 2
- Optimisation tests showed that combining methods and introducing variability improved performance
Results

Phase 3

- In a complex real-world problem (Search space $20^{130000}$) scaling issues restricted performance

- Solutions found met service level requirements, but held a lot of stock

- Tests comparing type-1 and interval type-2 showed no statistically significant difference
Summary

- Fuzzy sets are used where data is uncertain, vague or incomplete/incorrect.
- Interval type-2 fuzzy sets were used for an inventory planning model.
- Results were mixed.
- Many opportunities for improvement.
- Advantages of type-2 can be exploited.
  - Computing with words.
  - Group expert modelling.
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[Logos of collaborating organizations]