Insect Division of Labour Applied to Online Scheduling

Koen van der Blom

Leiden Institute of Advanced Computer Science
Leiden University

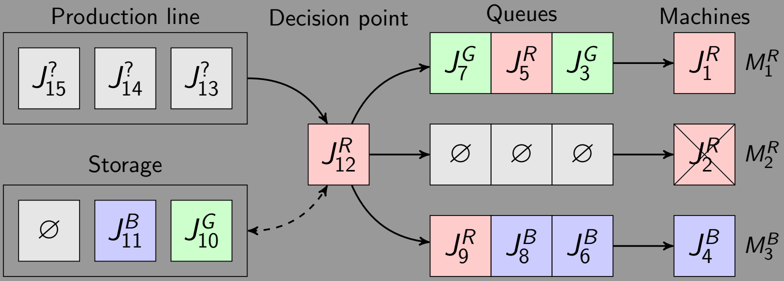
Master's Thesis Defence

Table of Contents

Introduction

- General Motors truck factory
- More colours than machines
- Colour changes are expensive
- Paint colours sequentially?
- Change colour for almost every truck
- Hire Morley et al. [8] [6] [7]
- Similarities to insect colonies
- Insect inspired models proven

Problem



$$P_m|online, r_j, S_{sd}, block, brkdwn, p_j = p|TST, F, \sum U_j$$

Algorithms

Previous work

- Market based approach (Morley et al. [8] [6] [7])
  - Bid based on queue and required colour
- Reinforced threshold model (Théraulaz et al. [12])
- Ant based approach (Campos et al. [2])
  - Bid based on queue and threshold for required colour
  - Kittithreerapronchai and Anderson [4]
- R-Wasps (Cicirello and Smith [3])
  - Probability to bid based on stimulus and threshold; select winner using a wasp like dominance contested based on the queue
  - Ant Task Allocation (Nouyan et al. [9] [10])
  - Meyyappan et al. [5]

Algorithms

Insect inspired models

- Fixed threshold (Bonabeau et al. [1])
- Self-reinforcement (Plowright and Plowright [11])
- Foraging for work (Tofts [13])

Algorithms

Proposed method

- Performance of those newly considered insect inspired models is unknown
- Improve on previous work
- Based on Nouyan et al. [9] [10]
    - Probability to bid includes the job type
    - Broken machines may compete for jobs
    - Include the remaining down time in the probability to win
    - Probability to win includes the threshold

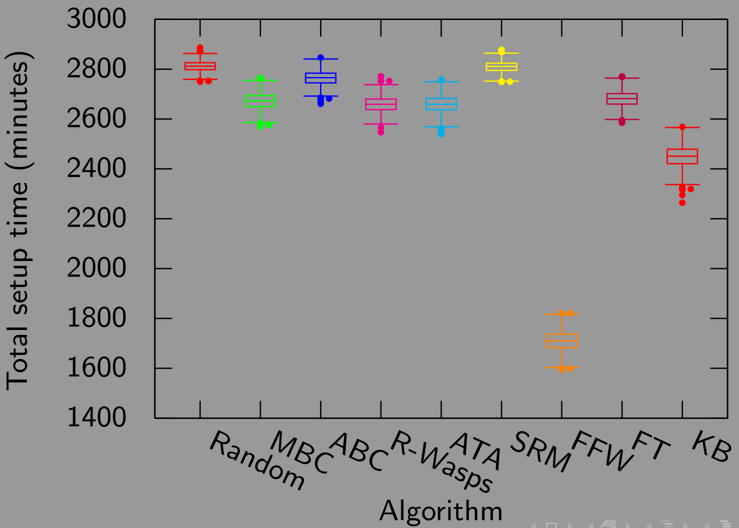
Experiments

- Many random factors in the problem make optimisation difficult
  - Probabilistic appearance of job types
  - Probabilistic job assignments
  - Random machine break downs
- No parameter optimisation
  - A single evaluation is unreliable
  - Even averages over 100 evaluations are inconsistent
  - Optimisation with primitive methods is time consuming
- Eight algorithms to optimise
- Use parameters from the authors or just choose something

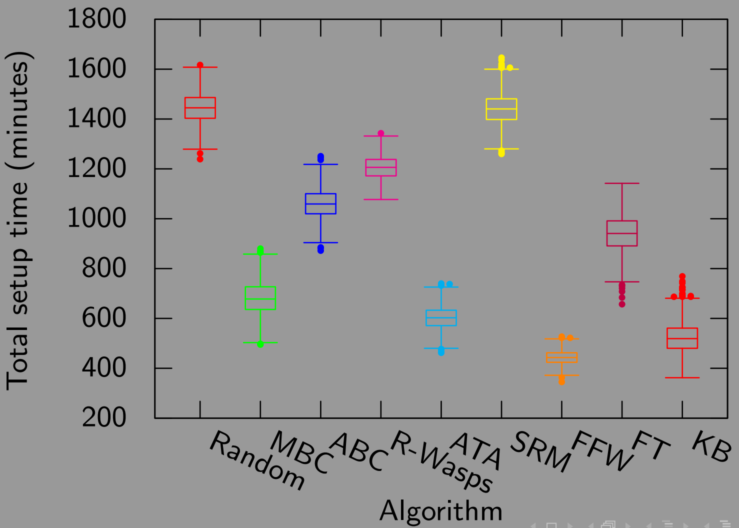
Experiments

- Experiment 1: Base situation
  - 1000 minutes, with one truck produced per minute
  - One minute time steps
  - 20 colours, uniformly distributed
  - 8 machines, with queue space for five trucks per machine
  - 0.05 probability a random machine breaks down per time step
  - Paint and setup times of three minutes
- Experiment 2: Base situation, except with an alternative colour distribution; one appearing 70%, one 15%, one 7%, one 4% and a uniform distribution of the remaining sixteen colours
- Experiment 3: Experiment 2, two trucks produced per minute
- Experiment 4: Experiment 3, break down probability of 0.25
- Experiment 5: Base situation, without break downs
- Experiment 6: Base situation, setup times of ten minutes

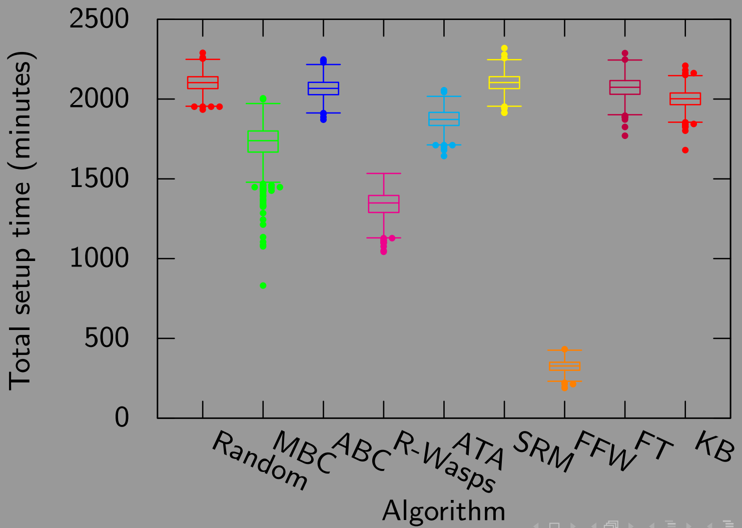
Results - Experiment 1 - Uniform colour distribution



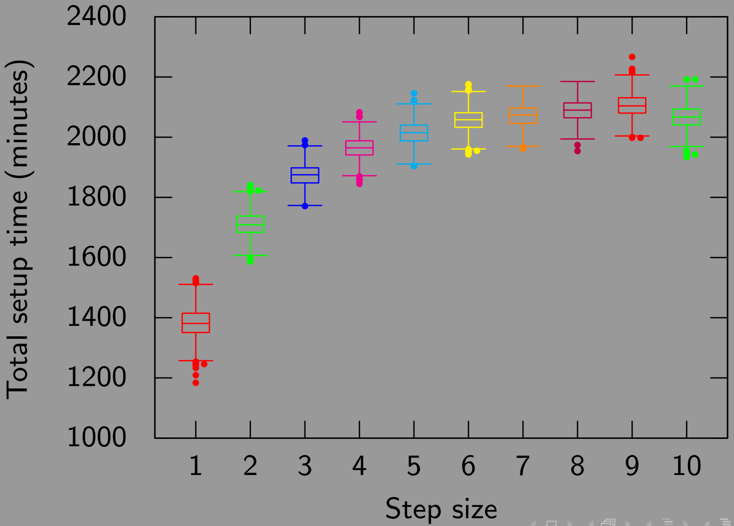
Results - Experiment 2 - Realistic colour distribution



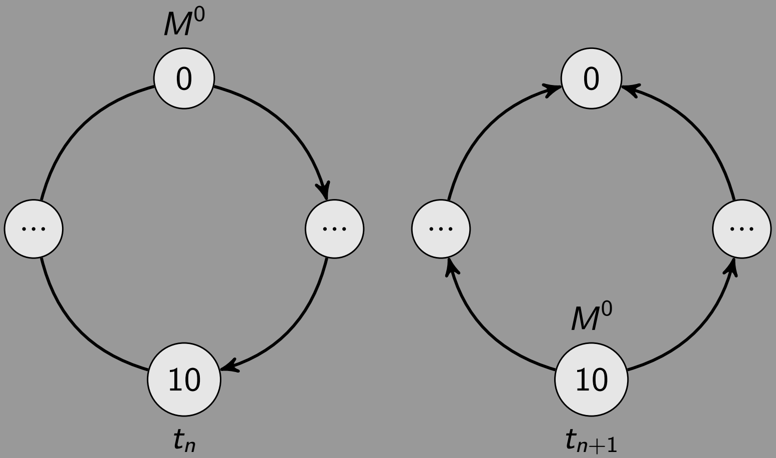
Results - Experiment 3 - Double production rate



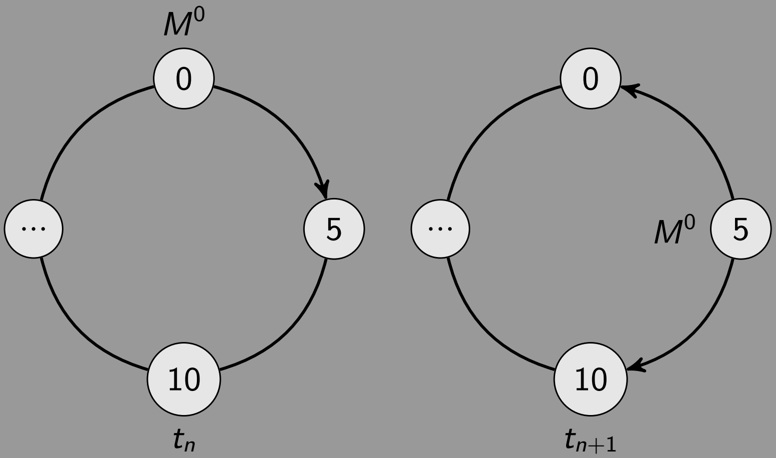
Results - Experiment 1 FFW - Uniform colour distribution



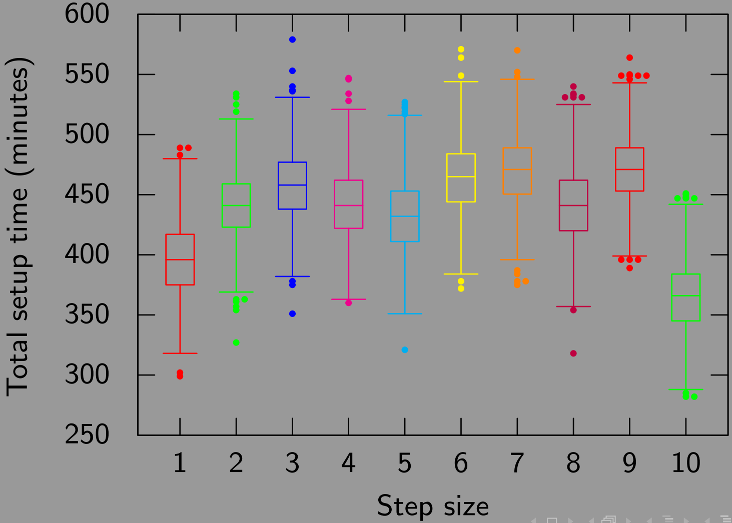
Results - Experiment 1 FFW - Uniform colour distribution



Results - Experiment 1 FFW - Uniform colour distribution



Results - Experiment 2 FFW - Realistic colour distribution



Conclusion

- Unexpected, great performance by foraging for work
- There may be biological relevance
- Proposed algorithm works well across the board on the most realistic problem

Further work

- Measure performance of more biological division of labour models
- Investigate parameter optimisation techniques for problems with many random factors
- Compare performance with tuned parameters
- Look at more complex situations, such as dynamic colour distributions
- Take into account more sophisticated problems, such as jobs with due dates

Summary

- Compared existing insect inspired algorithms
- Compared previously untested models
- Compared a proposed method
- Foraging for work does very well for minimising setup time
- My approach performs best overall in a realistic situation

Questions?

Thank you for listening

References I

[1] Eric Bonabeau, Guy Théraulaz, and Jean-Louis Deneubourg. Quantitative study of the fixed threshold model for the regulation of division of labour in insect societies. *Proceedings of the Royal Society of London. Series B: Biological Sciences*, 263(1376):1565–1569, 1996.

[2] Mike Campos, Eric Bonabeau, Guy Théraulaz, and Jean-Louis Deneubourg. Dynamic scheduling and division of labor in social insects. *Adaptive Behavior*, 8(2):83–95, 2000.

[3] Vincent A. Cicirello and Stephen F. Smith. Wasp-like agents for distributed factory coordination. *Autonomous Agents and Multi-agent systems*, 8(3):237–266, 2004.

[4] Oran Kittithreerapronchai and Carl Anderson. Do ants paint trucks better than chickens? markets versus response thresholds for distributed dynamic scheduling. In *Evolutionary Computation, 2003. CEC'03. The 2003 Congress on*, volume 2, pages 1431–1439. IEEE, 2003.

References II

[5] Lakshmanan Meyyappan, Can Saygin, and Cihan H. Dagli. Real-time routing in flexible flow shops: a self-adaptive swarm-based control model. *International Journal of Production Research*, 45(21):5157–5172, 2007.

[6] Richard E. Morley. Painting trucks at general motors: The effectiveness of a complexity-based approach. *Embracing Complexity: Exploring the application of complex adaptive systems to business*, pages 53–58, 1996.

[7] Richard E. Morley and Gregg Ekberg. Cases in chaos: complexity-based approaches to manufacturing. In *Embracing complexity: A colloquium on the application of complex adaptive systems to business*, pages 97–702, 1998.

[8] Richard E. Morley and Charles C. Schelberg. An analysis of a plant-specific dynamic scheduler. In *Proceedings of the NSF workshop on dynamic scheduling*, pages 115–122, 1993.

[9] Shervin Nouyan. Agent-based approach to dynamic task allocation. In *Ant Algorithms*, pages 28–39. Springer, 2002.

References III

[10] Shervin Nouyan, Roberto Ghizzioli, Mauro Birattari, and Marco Dorigo. An insect-based algorithm for the dynamic task allocation problem. *KI*, 19 (4):25–31, 2005.

[11] R. Christopher Plowright and Catherine M.S. Plowright. Elitism in social insects: a positive feedback model. In *Interindividual behavioral variability in social insects*, pages 419–431. Westview Press, 1988.

[12] Guy Théraulaz, Eric Bonabeau, and Jean-Louis Deneubourg. Response threshold reinforcements and division of labour in insect societies. *Proceedings of the Royal Society of London. Series B: Biological Sciences*, 265(1393):327–332, 1998.

[13] Chris Tofts. Algorithms for task allocation in ants. (a study of temporal polyethism: theory). *Bulletin of Mathematical Biology*, 55(5):891–918, 1993.