Insect Division of Labour Applied to Online Scheduling

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Master’s Thesis Defence
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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

\[ P_m | \text{online}, r_j, S_{sd}, \text{block}, \text{brkdw}, p_j = p | TST, F, \sum U_j \]
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
  - Kittithreeapronchaisi 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

![Boxplot showing total setup time for different algorithms.]

- **Random**
- **MBC**
- **ABC**
- **R-Wasps**
- **ATA**
- **SRM**
- **FFW**
- **FT**
- **KB**

**Algorithm**

**Total setup time (minutes)**
Results - Experiment 2 - Realistic colour distribution

The diagram shows the total setup time (minutes) for various algorithms. The algorithms tested are Random, MBC, ABC, R-Wasps, ATA, SRM, FFW, FT, and KB. Each algorithm is represented by a different color and marker, and the box plots indicate the distribution of total setup times across multiple runs or scenarios.
Results - Experiment 3 - Double production rate

The diagram shows the total setup time (in minutes) for different algorithms under the condition of a double production rate. The algorithms compared are Random, MBC, ABC, R-Wasps, ATA, SRM, FFW, FT, and KB. The box plots indicate the distribution of total setup times across multiple trials or conditions, with the central line representing the median, the boxes showing the interquartile range, and the whiskers indicating the range of data points.
Results - Experiment 1 FFW - Uniform colour distribution

Total setup time (minutes)

Step size

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Results - Experiment 1 FFW - Uniform colour distribution

\( M^0 \)

0

\( t_n \)

\( \cdots \)

\( 10 \)

0

\( \cdots \)

\( \cdots \)

\( t_{n+1} \)

\( M^0 \)
Results - Experiment 1 FFW - Uniform colour distribution

\[ M^0 \]

\[ 0 \]

\[ 5 \]

\[ t_n \]

\[ 10 \]

\[ M^0 \]

\[ 0 \]

\[ 5 \]

\[ t_{n+1} \]

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Results - Experiment 2 FFW - Realistic colour distribution

![Box plot](image)

- **Total setup time (minutes)**
- **Step size**

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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


References II


