

Advanced Concepts

Helmut Simonis

email: helmut.simonis@insight-centre.org
homepage: <http://insight-centre.org/>

ENTIRE EDIH
Insight SFI Centre for Data Analytics
School of Computer Science and Information Technology
University College Cork
Ireland

Constraint Based Production Scheduling

Acknowledgments

This publication was developed as part of the ENTIRE EDIH project, which received funding from Enterprise Ireland and the European Commission.

Part of this work is based on research conducted with the financial support of Science Foundation Ireland under Grant number 12/RC/2289-P2 at Insight the SFI Research Centre for Data Analytics at UCC, which is co-funded under the European Regional Development Fund.

Part of this work is based on research conducted within the ASSISTANT European project, under the framework program Horizon 2020, ICT-38-2020, Artificial intelligence for manufacturing, grant agreement number 101000165.

Key Points

- We present some more advanced concepts in scheduling
 - These occur in more specialized problem areas
 - Typically require more work on modelling
 - Solver support may be limited

1 Sequence Dependent Setup-Time

Sequence Dependent Setup-Time ✓

- Our usual disjunctive resource model assumes that we can change easily from one task to the next
 - There might be a cleaning/setup time required
 - This is part of the fixed duration part of a processStep description
 - In some cases it is more complex
 - On some machines there is a setup-time required which depends on both the previous and the next product
 - This time varies significantly between product combinations
 - Typically, the time depends on some properties of the products
 - The setup time is non-productive, and should be avoided when possible

Computed Setup-Time Matrix

- This needs to be computed from first principles, not maintained by hand!
 - Available as input data in JSON format

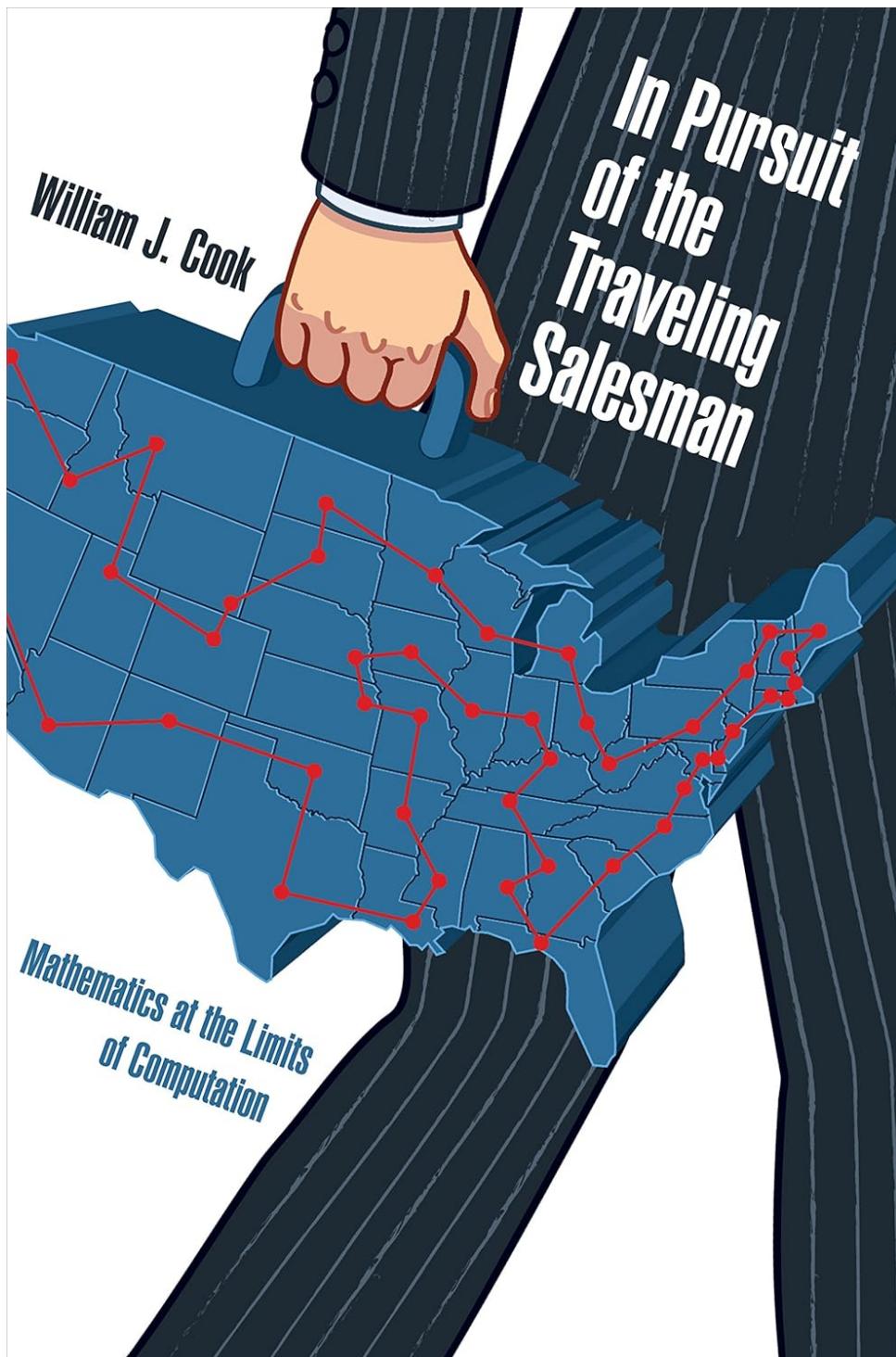
Relation to TSP

- Computing the optimal sequence of setup times is a variant of the *Travelling Salesman Problem (TSP)*
 - Another of the classical hard combinatorial problems
 - Due to the structure of the data, setup-time problems often are simpler to solve
 - Changing between very similar products needs no setup-time

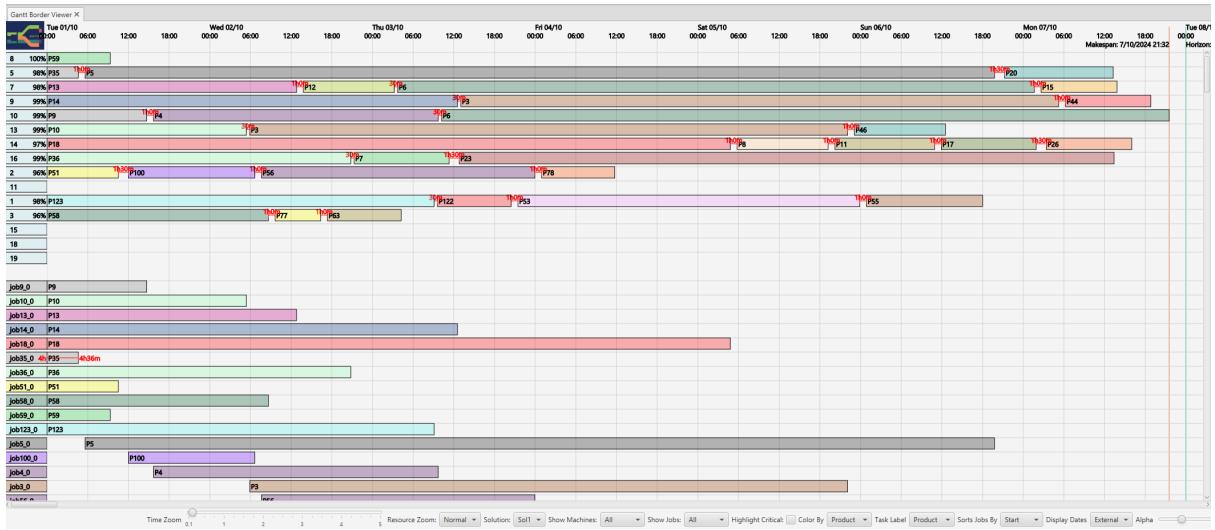
- Using a simple rule about product compatibility produces best results
- Example: dark-chocolate → milk chocolate → white chocolate → milk chocolate → dark chocolate
- Problems get more difficult when release/due dates need to be respected
- This is the equivalent to the *VRPTW* (*Vehicle Routing Problem with Time Windows*)

Xmas Shopping Hint

- W. Cook. In Pursuit of the Travelling Salesman. Princeton University Press, 2011
- Entertaining general science presentation of the TSP and related issues



Setup Times Constraints can be Included in Model



- Shown in Machine Gantt chart, enable display in Layout tab
- So far, only in CPO, not in CPSat model

Related Problem: Forbidden Transitions X

- For safety reasons, it may be forbidden to change from some product to some specific other products
- Contamination risk is considered too high
- Examples
 - In food production: Is this product peanut free?
 - In food production: Directly changing from dark to white chocolate is not allowed
 - In chemical plants: Contamination may lead to explosions
- These transitions are called *forbidden*, and must be avoided
- Careful, it is easy to paint yourself into a corner!

2 Transportation Time

Dealing with Transportation Times

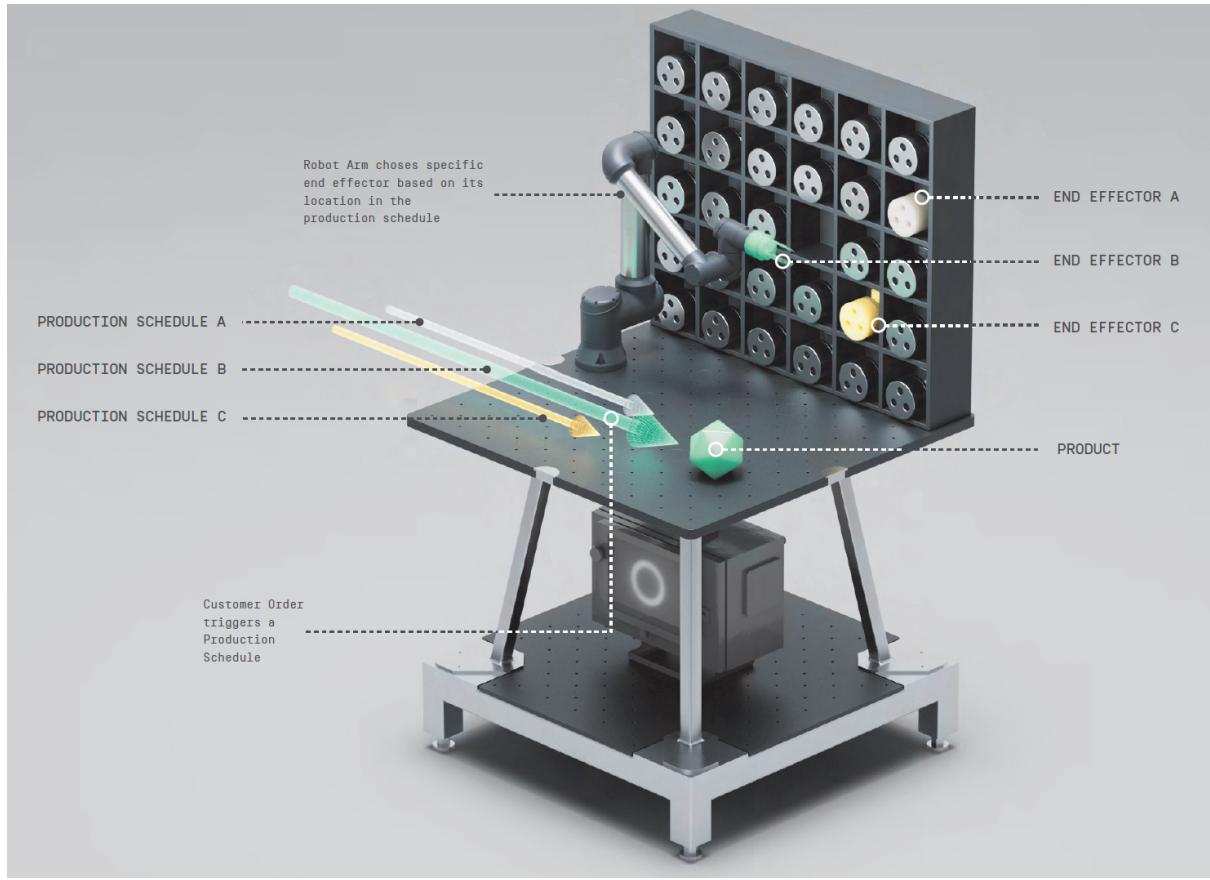
- Really two different problems
 - In one, the resources are in fixed locations, and we transport the jobs between the locations
 - In the other, the tasks are in fixed locations, and we transport the resources between them

2.1 Transportation of Materials

Transportation of Jobs

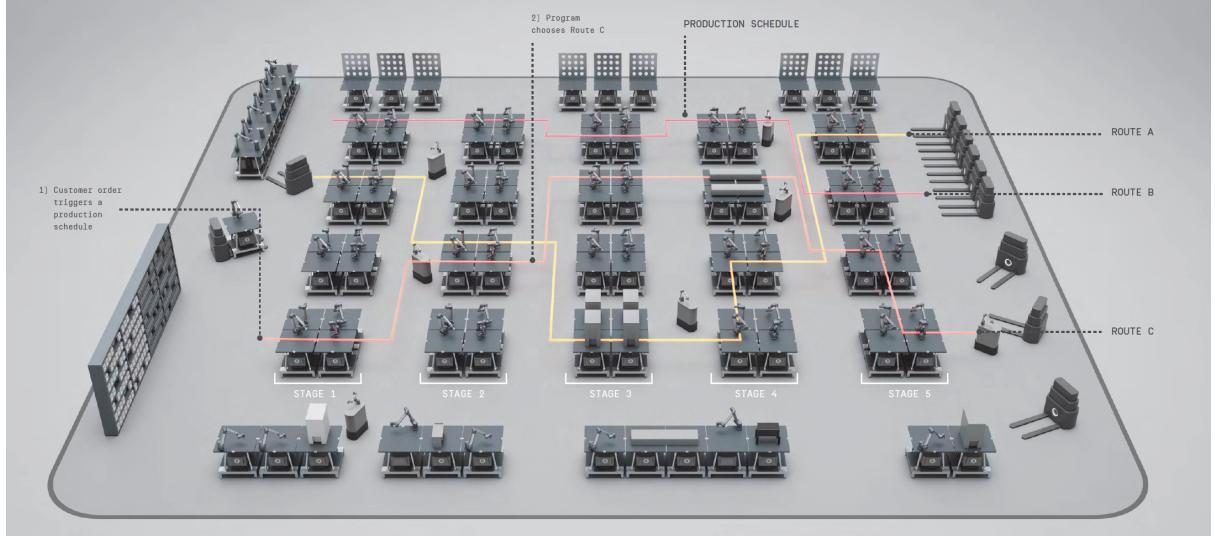
- Example from a project with J&J in Limerick
- Considering a *factory of the future* based on agile machines
- Robots that can be configured to perform many different tasks
- These robots may be inside one or more factories

- How to arrange them to minimize impact of transport on production



from J&J

Layout of Factor in Matrix Form



- Materials are transported between stations by moving robots
- Layout of factory determines delay caused by transport

Inclusion in Model (✓)

- Add location attribute to each resource
 - Include transport time as element in temporal constraints

More Complex Variant X

- Schedule the moving robots as well
 - Assume that an empty robot travels much faster than a loaded one
 - We can treat the robots as a machine choice resource for the transportation tasks

Even More Complex Variant X

- Schedule the moving robots as well
 - They move at the same speed empty and loaded
 - We can bring them from the end of one transport task to the start of the next one
 - This is a vehicle routing problem
 - In some industries, this is the harder problem than scheduling the plant itself
 - Torpedo scheduling in steel plant: rail cars holding molten steel, quantities limited

Torpedo Scheduling (CP 2016 Challenge)



(from ACP Website <http://cp2016.a4cp.org/program/acp-challenge/>)

2.2 Transportation of Resources/Personnel

Scheduling Service Visits X

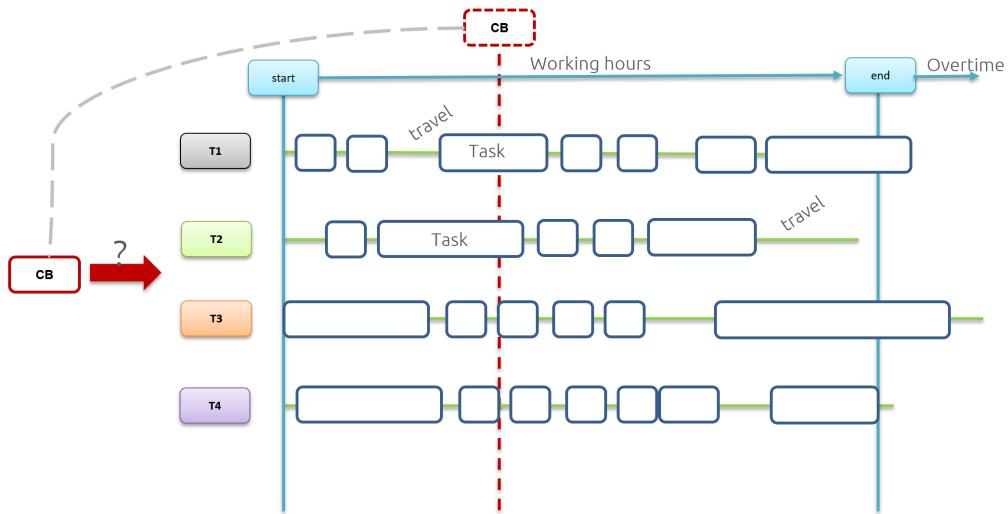
- Based on a project with UTRC-I, UTRC, OTIS
- Schedule visits to maintain equipment installed in customer premises
- Resources are the service engineers
- They have to travel between locations and perform work there
- The tasks are the maintenance operations required to keep equipment working
- Also called *Traveling Repair-person Problem*

Planning Maintenance Visits for Service Personnel



- Include single day trips, multi-day tours
- Most of the time spent at customer locations

Re-scheduling Problem



- How to react when a customer is trapped in an elevator
- All your engineers are on service calls
- *Who you gonna call?*

Advertisement

- This will be described in more detail in a new course
- AI Fundamentals: Skill Development Program on Transportation Optimization
- Arriving in 2025 at this location

3 Summary

Summary

- We presented some more advanced topics
 - Sequence dependent setup
 - Transportation time
- Not available in every solver
- Useful concepts when dealing with specific scheduling problems
- Leading to another *Skills Development Program*