Dynamical Handling of Straddle Carriers Activities on a Container Terminal in an Uncertain Environment - Swarm Intelligence Approach -

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Outline

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The CALAS project

- CALAS project : localizing precisely handling trucks on a container terminal
- Laser measure system and software
- 2 companies :
  - Laser Data Technology Terminal
  - *Terminaux de Normandie*

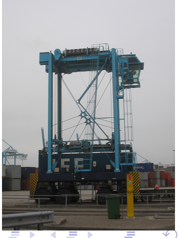
Objective of the CALAS project :

To know the state of the terminal, in real time, for both containers and trucks location.

Terminal description

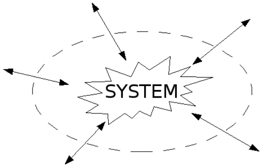
- Container terminal
- 3 main areas :
  - Ship handling
  - Stock area
  - Truck/Train handling

- Stock area contains many long rows of stacked containers
- Straddle carriers have to move containers from a place inside the terminal to another one
- 3 kinds of missions :
  - Preparing a ship (un)loading
  - Preparing a truck (un)loading
  - Optimizing stock area



System dynamic

- Open system means uncertain environment
- 3 kinds of unpredictable events :
  - Incoming missions
  - Trucks arriving time
  - Human behavior



Outline

VRPTW[1]

- **V**ehicle **R**outing **P**roblem
- **T**ime **W**indows

Goal

Optimizing the delivery routes of each truck

example of VRPTW : the Italian factory

- The factory produces toys and its vehicles deliver a set of stores
- Stores are spread all over the country and goods are carried by trucks
- Every truck has a restricted capacity and starts from the factory depot
- Deliveries must occur during a time interval and if a truck comes too early, it will have to wait

DVRPTW[6]

- Dynamic

Goal

Optimizing the new routes of each truck without recomputing from scratch

Dynamic Italian factory

- Italian factory problem
- While a schedule is running, stores are still allowed to ask for a delivery

(D)PDP

- DVRP where the goods have to be picked-up before being delivered

Goal

Optimizing both pickup and delivery routes

Pickup and Delivery Problem example : mail delivery problem

- A mail company employs a set of postmen
- They have to pickup mails from the mail boxes of the company
- Then, they must deliver them to their recipients as soon as possible

DSCPDPTW

- Dynamic Pickup and Delivery Problem class
- Vehicles can start from anywhere - they do not have to start from the depot
- 2 problems :
  - Minimize straddle carriers moves : shortest path problem
  - Minimize customers delays : scheduling problem

Problem dependencies

appropriate scheduling	$\Rightarrow$	shortest path concept
scheduling shortest paths	$\Rightarrow$	reducing straddle carriers moves

Goal

Solving these 2 interconnected problems

Outline

Ant Colony Optimization[3]

- ACO is a meta-heuristic
- ACO makes a solution appear thanks to the run of artificial ants into the solution space
- ACO is adapted to the dynamic nature of this problem :
  - Positive feedback : ants spread pheromone according to solution quality
  - Negative feedback : pheromone track evaporates progressively

Scheduling with Ant Colony

Ant Colony with **one colony** provides a sorted list of missions to accomplish.

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Colored ants[2] :

- every straddle carrier represents a colony with its own color
- ants are attracted by pheromones of their own colony
- ants are repulsed by pheromones of foreign colonies

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- every straddle carrier represents a colony with its own color
- ants are attracted by pheromones of their own colony
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Ant Colony with **many colonies** provides a sorted list of missions per straddle carrier.

Missions graph

The directed graph can be conceptualized as follows :

- Vertices :
  - 1 mission = 1 node
  - 1 straddle carrier = 1 colored node connected to all compatible missions
- Colored Arcs :
  - Compatibility between 2 missions for a straddle carrier

Ordering missions

We say that mission m_a is **prior** to mission m_b if the time window of m_a starts before the one of m_b

Mission compatibility

We say that mission m_a is **compatible** with mission m_b if m_a is prior to m_b

Example of a mission graph construction (1)

Example

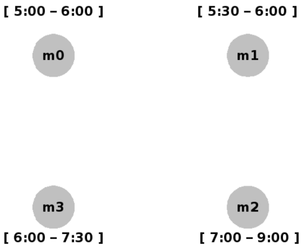
- Missions :

Name	Start	End
m0	5:00	6:00
m1	5:30	6:00
m2	7:00	9:00
m3	6:00	7:30

- Straddle Carriers :

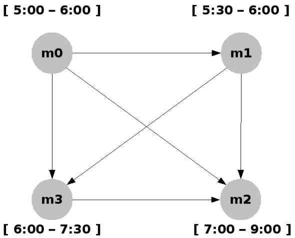
Name	Color	Compatiblility
s0	green	m0, m1, m2, m3
s1	blue	m0,m3

Example of a mission graph construction (2)



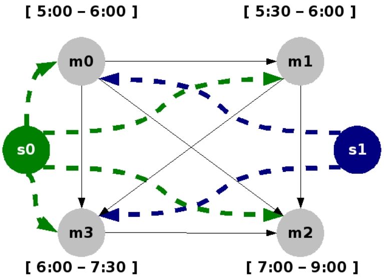
1 mission $\Longleftrightarrow$ 1 vertex

Example of a mission graph construction (3)



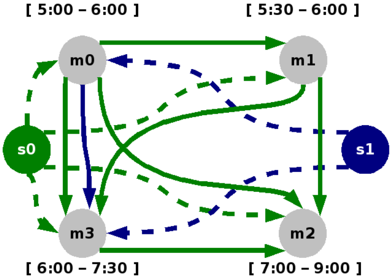
1 arc between two compatible missions

Example of a mission graph construction (4)



Adding nodes modeling straddle carriers and connecting them to every other vertices

Example of a mission graph construction (5)



Adding or Coloring edges between nodes according to their connectivity with the vehicles

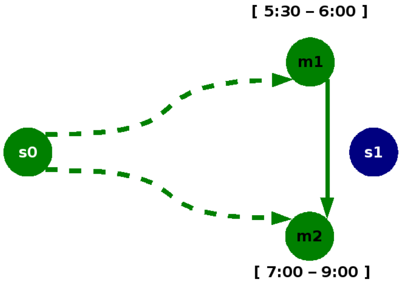
Algorithm description

Main algorithm

```
begin
| for each colony c do
| | for each ant a of c do
| | | choose an unvisited destination according to the pheromone track
| | | move towards it according to the speed of a
| | | spread pheromone according to the destination quality
| | end for
| end for
| evaporation
end
```

Solution

- The solution is the coloring of the nodes.
- When a straddle carrier is free, it chooses the mission of its color which has the highest pheromone rate.
- The chosen missions are removed from the graph and the algorithm continues running.

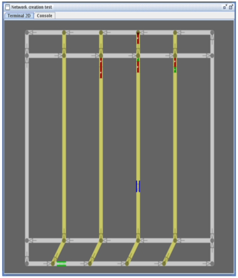


Outline

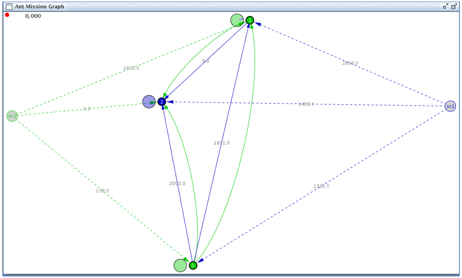
1. System description
2. Vehicle Routing Problem : state of the art
3. Ant Colony and Straddle Carrier Handling
4. Simulator
5. Preliminary Results
6. Conclusion

2 parallel views of the system

- Terminal implementation



- ACO modeling[4]



ACO $\Longleftrightarrow$ Terminal

Effects of ACO results must appear on the terminal and the terminal state must affect the ACO setting (mission graph)

Dynamism handling

A scenario file is read all along the execution of the simulation. It contains dynamic events.

Measure of dynamism

According to A. Larsen[5], we can measure how dynamic is a scenario by these two formulas :

- Degree of Dynamism (dod) $= \frac{\eta_d}{\eta_s+\eta_d}$
- Effective Degree of Dynamism (edod) $= \frac{\sum_{i=1}^{\eta_d} \frac{t_i}{T}}{\eta_s+\eta_d}$

η_s : number of static requests ;
η_d : number of dynamical requests.

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Preliminary results

- Test the relevance of both our modeling and our algorithm on simulated data
- Function of the measures of dynamism

	Static	Half Dynamic	Dynamic
dod	0	0.5	1
edod	0	0.25	1
End time	22693	22276	22693
Number of overrun tw	3	5	7
Overrun time penalty	6467	8477	12485

The exceeded time windows and the time penalties evolve in the same way that *dod* and *edod*.

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Conclusion

- The problem to solve belongs to the Dynamic Pickup and Delivery Problem with Time Windows class
- It does not totaly fit, so it is an original and unsolved problem
- Swarm intelligence has been used to solve it, containing :
  - Ant Colony System
  - Colored Ants
  - A Graph modeling
- A simulator is being developped and will allow to measure the solution relevance
- Priliminary results confirm that our modelling is able to handle dynamics

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Thank you for your attention

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