Disruption Management in Airline Operations Control
An Intelligent Agent-Based Approach

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FEUP – SSIIM 2012/2013 – 2012/10/18
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Airline Scheduling Problem
Airline Scheduling Problem

Revenue Management
- Passenger View
  - Publish Timetable
  - Fleet Assignment
- Aircraft View
  - Tail Assignment
- Crew View
  - Crew Pairing
  - Roster Maintenance
  - Crew Rostering

Disruptions Management
- Crew Recovery
- Aircraft Recovery
- Passenger Recovery

Long-term
- Short-term
- Day Operations

NIAD&R - Distributed Artificial Intelligence and Robotics Group
Airline Operations Control
Flight 103 with a schedule ETA in Rio at 11:00 did not departure yet from Lisbon due to a missing crewmember. The new ETD is 20:00 and the new ETA is 12:30. It has 230 passengers on board with the following connections:

20 to flight 231 – ETD 12:15
34 to flight 350 – ETD 12:00
60 to flight 412 – ETD 12:45

What is the best solution to solve this unexpected event?
Integrated Operational Control Center

- Maintenance Services
- Passenger Team
- Aircraft Team
- Flight Dispatch
- Crew Team
- Supervisor
- Line Maint

- Cust. Serv.

72-24 hours - Day of Operation - 12-24 hours
Integrated AOC with HUB

HUB Supervisor

AOCC Supervisor

Passenger Team

Maintenance Services

Aircraft Team

Crew Team

Flight Dispatch

- 72-24 hours

- Day of Operation

- 12-24 hours
Decision Control Center

AOCC Supervisor

Crew Team

Passenger Team

Maintenance Services

Flight Dispatch

Aircraft Team

72-24 hours → Day of Operation → 12-24 hours
Decision Control Center with HUB

HUB Supervisor

AOCC Supervisor

Crew Team

Flight Dispatch

Passenger Team

Maintenance Services

Aircraft Team

72-24 hours — Day of Operation — 12-24 hours

Cust. Serv.

Line Maint.
Operational Problems
Disruption Management Process
The Vision
Future Airline Operations Control Centres should be **Automatic, Autonomous** and include **Learning** capabilities. **Monitoring** the operation, **Detecting** Problems that might affect the operation, **Finding** solutions to the problems, **Choosing** the best solution, **Updating** the operational plan accordingly and increase **Robustness** of future plans, should be done **Without** or with the **Minimum Human Intervention**.
Automation:

• Repetitive tasks:
  – Monitoring, Detecting, Finding, Updating...

Autonomy:

• Decision:
  – When to consider an event as a problem
  – Choose the best solution

Learning:

• Solving similar problems
• Increase robustness by avoiding repetitive problems
Is this Vision an Utopia?

**B707 – 50, 60,70’s – 3 Crew**

**L1011 – 1968 ... - 3 Crew**

Boeing 707 cockpit
Is this Vision an Utopia?

A330 – 1994 ... – 2 Crew

A350 – 2013 - 2 Crew
What about the future cockpit?

**How are they doing it?**
- Computers perform tasks that were done by humans
- More than one computer to perform the same task
- When two computers disagree a third makes the final decision

Very soon (according to Airbus) one man crew!
Automation
  • Repetitive tasks

Autonomy
  • Decision

Learning
  • Robustness

Redundancy:
  • Agents performing same task in parallel
  • A third agent that decides when two disagree
Future AOCC – New Concept

Future AOCC: A new concept in aircraft operations and maintenance is proposed, integrating advanced artificial intelligence and robotics technologies. The system aims to enhance efficiency, safety, and customer service.

Key Components:
1. Line Maint. - Maintenance personnel are directly connected to the system for efficient maintenance services.
2. Cust. Serv. - Customer service agents are integrated to provide seamless customer support.
3. Flight Dispatch - Coordination for flight schedules and operations.
4. Data Link - Communication between aircraft and ground support.

Operational Timeline:
- 72-24 hours prior to operation: Preparation and planning phase.
- Day of Operation: Active management and coordination.
- 12-24 hours post-operation: Post-processing and analysis.
Can We Do It in One Step?

Step 1: Automation
• Keep humans in the loop to validate info.

Step 2: Autonomy
• Ask humans for final approval.

Step 3: Learning
• Get humans opinion.

Step 4: Redundancy
• On our way to full autonomy....

Human Factors are Very Important!
Agent-Based System for AOC
Decision Mechanisms and Criteria
Levels of Negotiation

1. Manager Agents Level
   - Agents cooperate (by exchanging information) to find an integrated solution (one that considers the impact on the three dimensions problem)
   - Select the best candidate solutions with lowest Total Operational Costs

2. Specialist Agents Level
   - Each agent has a specific expertise (different resolution algorithm)
   - Run in parallel trying to find the best candidate solutions
   - Total Operational Cost is the criteria
• **Multi-Attribute:**
  – Each with a set of preferred values and domains

• **Qualitative Feedback:**
  – Organizer agent classifies the values of each attribute and gives feedback

• **Several Rounds**

• **Inter-agents negotiation:**
  – Respondent agents negotiate in each round to be able to complete their knowledge and present a proposal

• **Learning:**
  – Agents adapt their strategy during proposal formulation

• **Multiple agent types and roles:**
  – Organizer, Respondent, Initiator, Participants

• **Suitable for competitive and cooperative environments**
Manager Level - GQ-Negotiation

**Event time:** 18-09-2009 12:39
**Event type:** AC
**Resource Affected:** CS-TTG
**Resource Type:** A319
**ETR:** 110
**Flt_date:** 18-09-2009
**Flt_Nbr:** 686
**STD:** 13:20
**STA:** 15:50
**ETA:** 16:10
**From:** LIS
**To:** LUX
**Dep_Delay:** 20
**Bus_Pax:** 1
**Econ_Pax:** 128
**Schd_Trip_Time:** 02:30
**Est_Trip_Time:** 02:50
**Schd_AC_Cost:** 1084
**Schd_Crew_Cost:** 1745
**Schd_Pax_Cost:** 0

**Send Problem**

**Close Problem**

**Manager**

**CFP**

**Search Best Crew Solution**

**Search Best Pax Solution**

**Search Best AC Solution**

**Supervisor**

**Prepares CFP**

**Does not Accept**

**Accepts**

**Evaluates bids**

**Proposes full solution**

**Request pax and ac solution considering crew restrictions**

**Keep**

**Request crew and ac solution considering pax restrictions**

**Request crew and pax solution considering ac restrictions**

**Ask Approval**

**Choose winner**

**Provides feedback**

**Proposes new CFP (feedback)**

**Prepares new CFP**

**Evaluates bids and replies with feedback**

**Proposes**

**Provides feedback**

**Accepts**

**Does not Accept**

**Ask Approval**

**Proposes**

**Search Best Pax Solution**

**Search Best AC Solution**

**Search Best Crew Solution**

**ACTION, RESOURCE, RES_TYPE, DELAY, COST**

**NEAREST, 24164.6, NB, 10, 1900**

**ACTION, DELAY TT, COST**

**KEEP, 20, 2000**

**ACTION, RESOURCE, RES_TYPE, DELAY, COST**

**DELAY, CS-TTG, A319, 20, 1300**

**DLY AC COST AC**

**DLY CRW COST CRW**

**DLY TT COST PAX**

<table>
<thead>
<tr>
<th>20</th>
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<tbody>
<tr>
<td>18</td>
<td>15</td>
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<td>15</td>
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<td>20</td>
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<tr>
<td>1230</td>
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<td>1300</td>
<td>1900</td>
</tr>
<tr>
<td>1500</td>
<td>1900</td>
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**E_{round} = \frac{\alpha (d_{a_{max}}) + \beta (d_{c_{max}}) + \gamma (d_{t_{max}}) + \delta (c_{a_{max}} + c_{c_{max}} + p_{c_{max}})}{\alpha + \beta + \gamma + \delta}**
Total Operational Cost

\[ tc = dc + \beta qc \quad \beta \in R, \beta \geq 0 \]

dc = Direct Operational Costs
qc = Quality Costs
\[
dc = cc + fc + pc
\]

cc = \[\sum_{i=1}^{\lvert F \rvert} \sum_{j=1}^{\lvert C \rvert} (\text{Salary}_{i,j} + \text{Hour}_{i,j} + \text{Perdiem}_{i,j} + \text{Hotel}_{i,j} + \text{Dhc}_{i,j})\]

where
\(i \in F; F = \{\text{all flights in solution}\}\)
\(j \in C; C = \{\text{all crewmembers in flight}\}\)

\[
f c = \sum_{i=1}^{\lvert F \rvert} (\text{Airp}_i + \text{Service}_i + \text{Maint}_i + \text{Atc}_i + \text{Fuel}_i)
\]

where
\(i \in F; F = \{\text{all flights in solution}\}\)

\[
\[
p c = \sum_{i=1}^{\lvert F \rvert} \sum_{d=1}^{\lvert D \rvert} (\text{Meals}_{d,i} + \text{PHotel}_{d,i} + \text{Comp}_{d,i})
\]

where
\(i \in F; F = \{\text{all flights in solution}\}\)
\(d \in D; D = \{\text{all delayed passengers in flight}\}\)
Quality Operational Cost

$$qc = \alpha \sum_{i=1}^{|F|} \sum_{p=1}^{|PP|} (P_{p,i} \times C_{p,i})$$

where
- $i \in F; F = \{\text{all flights in solution}\}$
- $p \in PP; PP = \{\text{flight passengers profiles}\}$
- $P = \text{number of passengers of profile } p$
- $C = \text{delay cost of each passenger on profile } p$
- $\alpha = \text{coefficient to convert to monetary costs}$

- Define **passenger profiles** in each **flight** (surveys, booking info...)
- **Quantifying** the **importance** of the **delay** to each **profile** (surveys)
- **Get pax profile** for disrupted flights from **boarding information**
What is Keeping us Busy
We are Working on

• Finish implementation **GQN Negotiation Protocol:**
  – Q-Learning (Manager’s level)
• Implementing more Specialist Agents:
  • Different Scheduling Algorithms
  • Include Planning Algorithms.
• Add **learning capabilities** to the MAS:
  • Apply **similar solutions** to **similar problems**
  • Improve the **robustness of future schedules**
2D and 3D Data Visualization

DEMO

<table>
<thead>
<tr>
<th>Aircraft</th>
<th>Crew</th>
</tr>
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<tbody>
<tr>
<td></td>
<td></td>
</tr>
<tr>
<td>Tail number</td>
<td>CSTTC</td>
</tr>
<tr>
<td>Name</td>
<td>Fernando Pessoa</td>
</tr>
<tr>
<td>Model</td>
<td></td>
</tr>
<tr>
<td>Fleet</td>
<td>NB</td>
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<tr>
<td>Cruise speed (km/h)</td>
<td>900</td>
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<tr>
<td>Range (km)</td>
<td>5700</td>
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<tr>
<td>Min. safety cabin crew</td>
<td>3</td>
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<tr>
<td>Seat capacity</td>
<td>132</td>
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<table>
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<th>Disruption type</th>
<th>Resource type</th>
<th>Resource ID</th>
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<tr>
<td>Problem</td>
<td>CRW</td>
<td>00000.0</td>
<td>25</td>
</tr>
<tr>
<td>Problem</td>
<td>CRW</td>
<td>00000.0</td>
<td>25</td>
</tr>
</tbody>
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Map showing flight details with locations in Spain and Portugal.
We are Working on

• **Include more metrics and restrictions/costs in our MAS:**
  - Airport operational restrictions/costs
  - Airport Peak Performance

• **Developing a framework that captures the commonalities of disruption management.**

• **Developing an IDE (Integrated Development Environment) that allows to visual build MAS for disruption management in airline operations control and other similar domains.**
Learning Applied in Automated Negotiation on Operational Control Centers

At LIACC/NIADR we have developed a MAS that represents an AOCC (MASDIMA). We want the agents to learn how to formulate new proposals during negotiation.

Possible methods to use

Q-Learning

Additional Information

This work can be used totally on the dissertation Human-in-the-loop and learning in automated negotiation presented by TAP Portugal.

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Study of Techniques to Derive Strategies to Initiate Automated Negotiations

At LIACC/NIADR we have developed a MAS that represents an AOCC (MASDIMA) that uses automated negotiation. The goal of this work is to study possible techniques or methods to use to derive automatically strategies that the supervisor agent can use to initiate a negotiation, using not only the information about the specific problem to be solved but, also, information about previous problems.

Possible methods to use

Case Based Reasoning (CBR), ..... 

Additional Information

This work can be used totally or partially on the dissertation *Learning with the Past: Deriving Strategies to Initiate Automated Negotiations* presented by TAP Portugal.

Contacts: 

António Castro (antonio.castro@fe.up.pt)
Title

Problem Resolution Strategies Applied on Airline Operations Control Centers

Description

At LIACC/NIADR we have developed a MAS that represents an AOCC (MASDIMA). We want to study the best strategies (through the use of heuristics or meta-heuristics) to be used by the agents to solve the problems that appear during daily operations and integrate it in our negotiation protocol. There is already an agent that implements a SA algorithm to the aircraft problem and another the Dijkstra

Possible methods to use

Ant Colony Optimization (ACO), Particle Swarm Optimization (PSO), Genetic Algorithms (GA), Other ..... 

Additional Information

This work can be used totally or partially on the dissertation: “Studies of Evolutionary Computation applied on Operational Control Centers” presented by LIACC/NIADR.

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Thanks for your attention!

Any Questions?

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