Simulating Air Traffic Control Ground Operations: Preliminary Results from Project Modern Taxiing

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26 November 2014
Project Modern Taxiing

• Current taxiing operations are expensive: e.g. fuel, time, emissions
  – Reliance on aircraft’s main engines
  – Average taxiing time of 20 minutes around Charles-de-Gaulle
• Forecasted increases in traffic are a good opportunity to introduce automation
  – On-ground vehicles, automation for air traffic control officer (ATCO)
• How can we effectively introduce this technology?

Explore **automated taxiing options** that would enable **varying levels of automated assistance** and support the **technology transition period** in a non-intrusive manner.
• Fleet of autonomous **taxi robots** (TaxiBots) at airport
  – Tractors that can tow the aircraft to and from the runway

• Percentage of aircraft equipped with DataLink
  – eTaxi: **e**lectronic **Taxiing**, autopilot system in the cockpit

• Intelligent ATCO interface
  – Smart algorithms for TaxiBot management, conflict detection, path suggestion, etc
Questions to be answered

- How many TaxiBots will be added to operations?
- How will the TaxiBots be managed by the ground ATCO?
  - Possibly doubling number of vehicles on taxiways
- Where and what should we automate to help the ATCO?
- What and how will this information be provided to the controller?
- How will this work evolve with changes to the aircraft fleet?
Where are we: Project-level

- Three human-in-the-loop experiments
  1. **Baseline/current technologies**: paper flight strips, radio communication
  2. **Interface**: with decision support system, conflict detection, etc
  3. **TaxiBot/eTaxi**: Interface + technology for ground operations

Currently wrapping up Exp 1, towards end of development for Exp 2

- **Today’s talk**
  - Discussion of Validation Plan
  - Simulation Facility
  - Preliminary Results from first Experiment
  - Preview of Exp 2
• South end of Roissy Charles de Gaulle Airport (Paris, France)
• Ground controller only
  – Local, Apron control, North ground are simulated
• Evaluating current and futuristic air traffic levels
Validation Plan

Three experiments, several mini-experiments/workshops
• 3 x 2 full factorial design
• Automation: three levels (corresponding to three experiments)
  – Baseline
  – Interface
  – TaxiBot/eTaxi
• Scenario: two levels of difficulty
  – Combination of traffic load and activity
  – **Medium**: traffic load of 50 movements/hr, standard activity
  – **Hard**: traffic load of 70 mvts/hr, standard activity + change in QFU
• Solicit ideas and remarks on the platform and automation
• Full experiment not required, <5 controllers, specialists
  – Feb: Scenario definition, path suggestion improvements
  – July: Finalization of scenarios
  – Oct: MoTa workshop on taxibots, interaction, algorithm
  – Nov: Conflict detection, automation level modality
• Ideas for future
  – **Finalization of parameters: timing of warning (and possible correlations with traffic load); managing taxibot return**
  – Appropriateness of solutions proposed by algorithm
  – Maximum capacity of traffic managable by a singular CDG controller with MoTa
Each scenario takes about 35 minutes

- Restricted Zone
- Pilot Error
- Towed Aircraft
- Taxiway closure (aircraft breakdown)
• Idea is to compare operational and neurophysiological responses to each event, with and without automation assistance

• Other degrees of conflict are noted
  – Assignment of Aircraft Priority
  – Localized optimization (e.g. shortcuts)
Dependent Variables

Operational
- Throughput
- Fuel consumption
- Taxi-in, taxi-out time
- Number of bottlenecks

Subjective
- Workload (TLX)
- Situation awareness (SART)
- Trust in technology (SATI)
- Remarks on the technology

Behavioral
- Number of actions
- Clarity of commands
- Deviation from ideal trajectory

Neurophysiological
- Occular (eyetracker)
- Cardiographic (ECG)
- Cerebral activity (EEG, Cz)

* Solutions for Human-Automation Partnership in European ATM (SHAPE) Automation Trust Index
• Pool of international ATCOs: active, retired, instructors
  – Small and large airports, Charles-de-Gaulle
• Twelve participants per experiment (36 individuals total)
• Matched demographics between experiments
  – Tests for CDG memory retention between experiments
• Each session is 3 hours long
  – Airport manuals/maps sent prior to each experiment
  – **Practice**: Open discussion about CDG layout
  – **Calibration**: eyetracker, electroencephalogram (EEG), electrocardiogram (ECG)
  – **Run 1**: Medium or Hard
  – **Run 2**: Medium or Hard
  – Subjective measures are collected after each run, overall comments at end
Simulation Facility

Ecole Nationale de l’Aviation Civile
Toulouse, France
ATC Tower simulator

- External view is based on FlightGear
- The MoTa platform centered around ivy bus
Preliminary Results

10 participants: 4 CDG, 6 non-CDG
- **Medium**: max of 31 movements in 35 minutes
- **Hard**: max of 41 movements in 35 minutes
  - One ATCO handling all traffic, rather than splitting into two zones
- Scenarios designed for higher rates, ATCOs can advance aircraft
Results are shown for taxiing time through south ground sector only:
- Taxiing from North usually adds another 7-10 minutes
- Aircraft simulated to accelerate at max possible under velocity constraints at airport
- Will likely normalize this time to shortest standard route
Subjective measures

- **Workload**: NASA Task Load Index (TLX)
  - 1 is low workload, 7 is high

Expected difference in scores
• **Situation Awareness** Rating Technique (SART)
  – 1 is low situation awareness, 7 is high
Subjective measures

- SHAPE (Solutions for Human Automation Partnerships in European ATM) Automation Trust Index (SATI)
  - 0 is little degree of trust, 6 is high degree

I have confidence in the automation

Useful
Reliable
Precise
Comprehensible
Robust

More Trust in Auto
Less Trust in Auto
• Evaluate participant response (heart rate, cerebral activity, pupil dilation, reaction time) to each event (pilot error, restricted taxiway, taxiway closure, tractor, change in QFU)
• Noting: # of aircraft affected, possible collisions, etc
• In progress ... !
Preview of Experiment 2

Interface with conflict detection algorithm, path suggestion
• Automation
  – Use of common A-SMGCS concepts
    • Clearance monitoring
    • Conflict detection (short-term and strategic)
    • Path suggestion based on airport rules
    • DataLink

• Novelties
  – Shared authority between algorithm and ATCOs
  – Exploration of Multi-Agent System (MAS) algorithm for conflict resolution proposal
• Human-Machine Interface
  – Label-based interactions (and an additional timeline)
  – Exploring multimodality: voice and gesture recognition, eye gaze
• Path input
  – Validate proposed route if it fits
  – Rapid interaction to allow user-defined route
• Wide set of clearance types to match actual controller methods (and to keep automation in the loop)
  – Give way, follow this aircraft, hold short of, etc.
• TaxiBot interaction
  – Grouping TaxiBots to minimize radar footprint (match routes)
  – Exploring methods to communicate Aircraft priorities between:
    • TaxiBot with Aircraft + Aircraft
    • TaxiBot + Aircraft

• More workshops and interactive sessions planned for 2015
  – Evaluating methods of information representation to ATCOs (e.g. events)
  – Possible parallel study regarding the integration of DMAN information

• Further reflection on procedure evolutions required
• Use of MAS modeling for taxiBot simulation
Project MoTa is exploring the usage of autonomous TaxiBots, eTaxi, and an intelligent interface to permit varying levels of automation that can transition and support the ground air traffic controller to future traffic loads.

Three experiments are planned to evaluate the three stages of MoTa: baseline, interface, automation. We are between Experiments 1 and 2. Mini-experiments to iterate on and explore side concepts continue.

Our Air Traffic Control Tower simulator is simulating two scenarios, Medium (current) and Hard (futuristic) and is capable of evaluating other scenarios. In addition to operational and subjective measures, we are also collecting behavioral and neurophysiological data.
Questions?

Acknowledgements
F. Lancelot, R. Benhacène, G. Granger, M. Traoré and the rest of the Project MoTa team
Centre Aéronautique et Spatial (ISAE)
Aeronautical Computer Human Interaction Laboratory (ENAC)

This work is co-financed by EUROCONTROL acting on behalf of the SESAR Joint Undertaking (the SJU) and the EUROPEAN UNION as part of Work Package E in the SESAR Programme. Opinions expressed in this work reflect the authors’ views only and EUROCONTROL and/or the SJU shall not be considered liable for them or for any use that may be made of the information contained herein.