Autonomy, Authority and Human Interaction Challenges in Air Transportation Systems

Hamsa Balakrishnan
Massachusetts Institute of Technology

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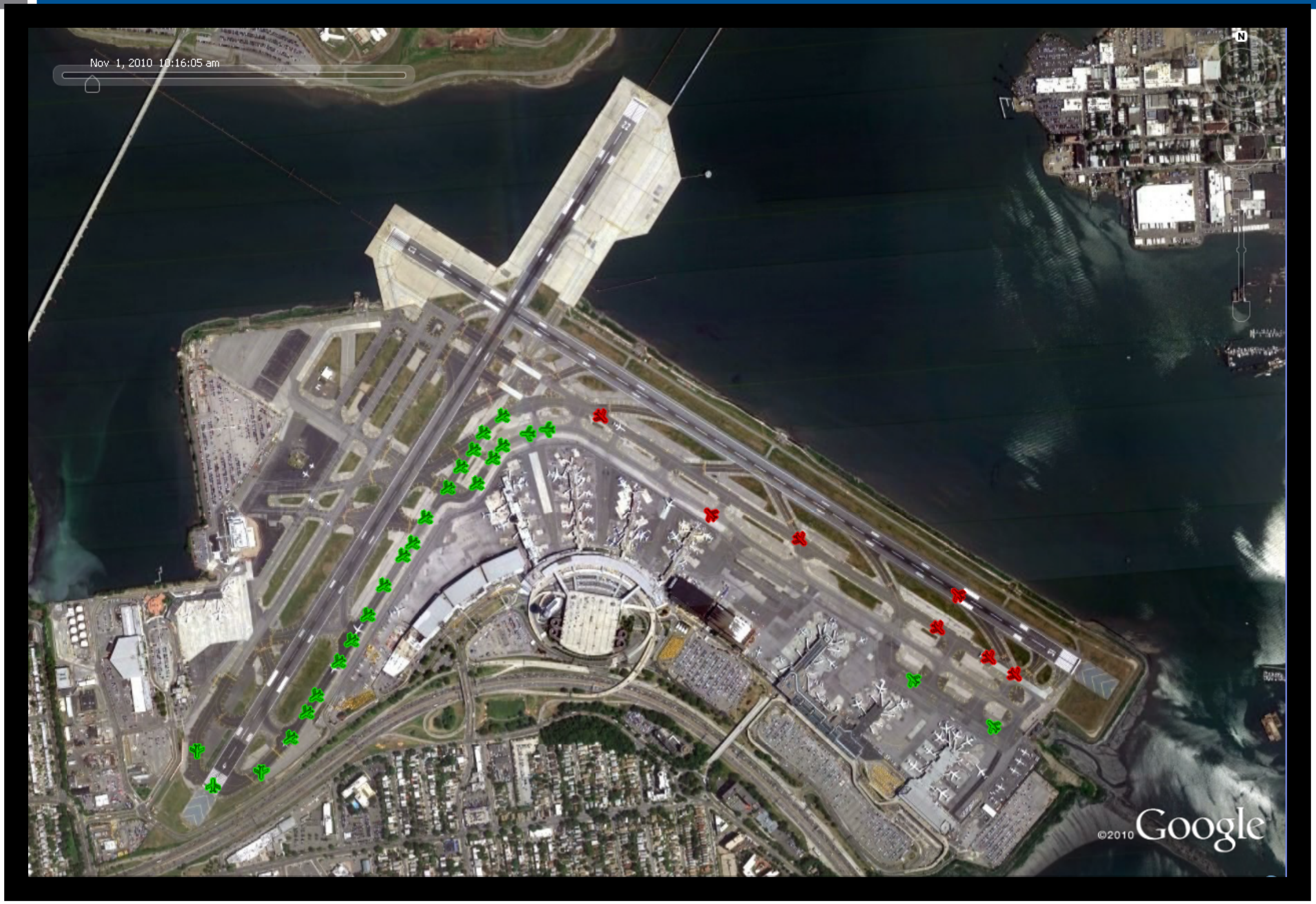
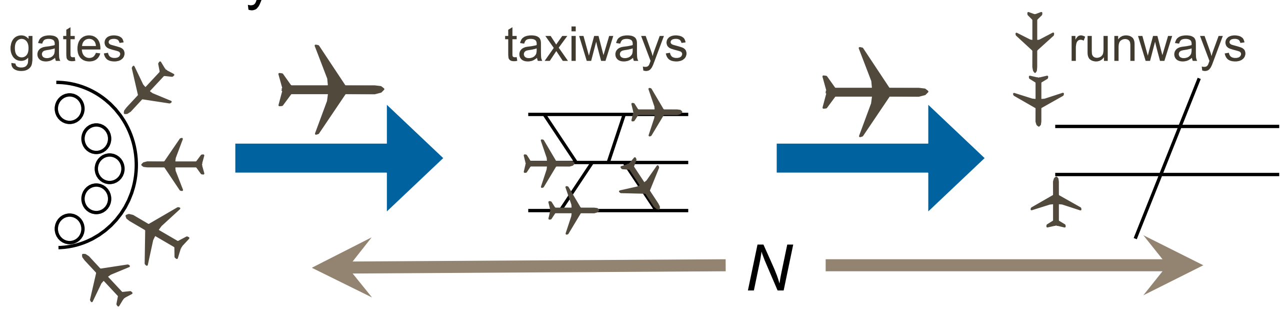
Problem: Airport surface congestion



Solution: Pushback Rate Control

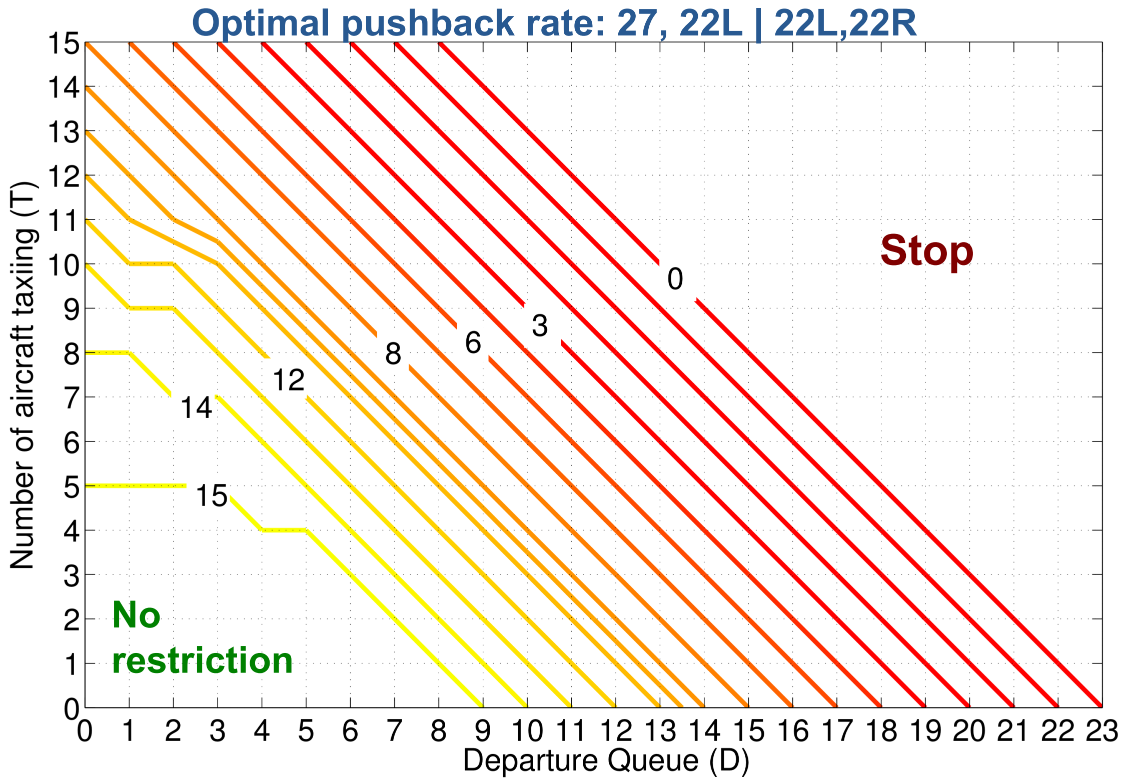
- Aircraft pushback from gates, start their engines, and then taxi until they takeoff



- Control pushbacks in order to maintain runway utilization while avoiding excessive levels of congestion
- Key challenges:
  1. How do we design the control strategy?
  2. How do we implement control strategy?
  3. How do we interface with human controllers?

1. Designing control strategy

- Dynamic control problem that **recommends pushback rate** to maintain departure throughput, given taxiway & runway queues
  - **Data-driven modeling** of runway processes and system dynamics
  - **Optimal pushback rate** to balance runway throughput and congestion



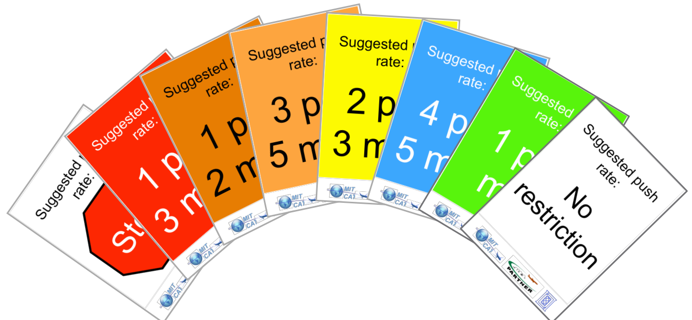
Simaiakis and Balakrishnan, American Control Conf., 2012.

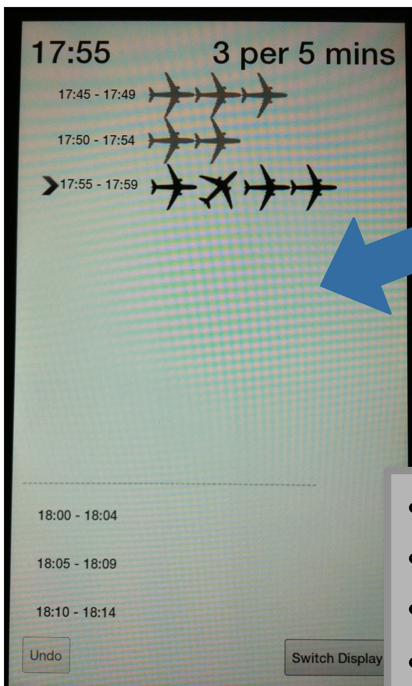
2. Implementing control strategy

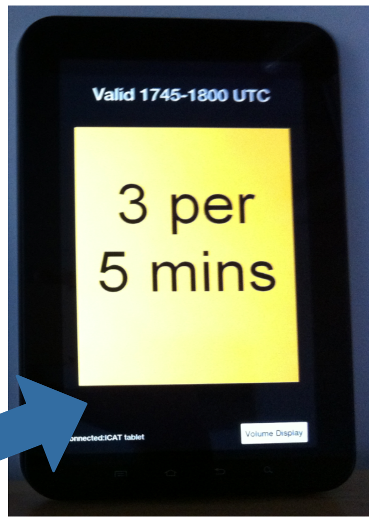
- On-off control does not work in practice
  - Air traffic controllers are humans, not automata
  - Rather than release an aircraft every time that a flight takes off, controllers prefer a rate at which to let aircraft pushback from their gates
  - **Pushback Rate Control**
  - Rate is updated periodically

3. Interfacing with human controllers

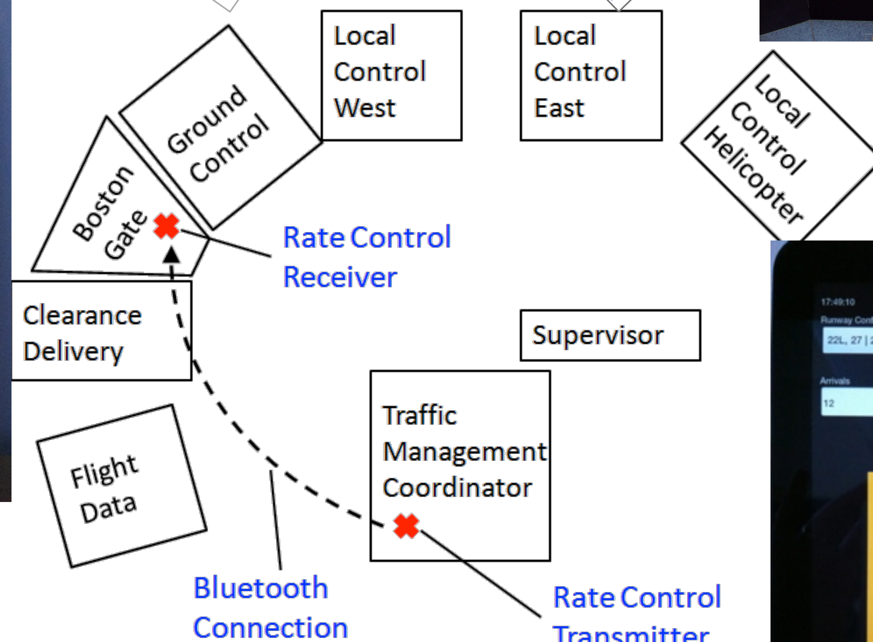
- Suggest pushback rate (color-coded cards or a tablet display)

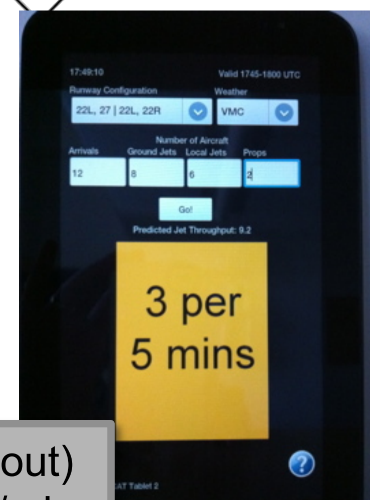






Alternative display modes

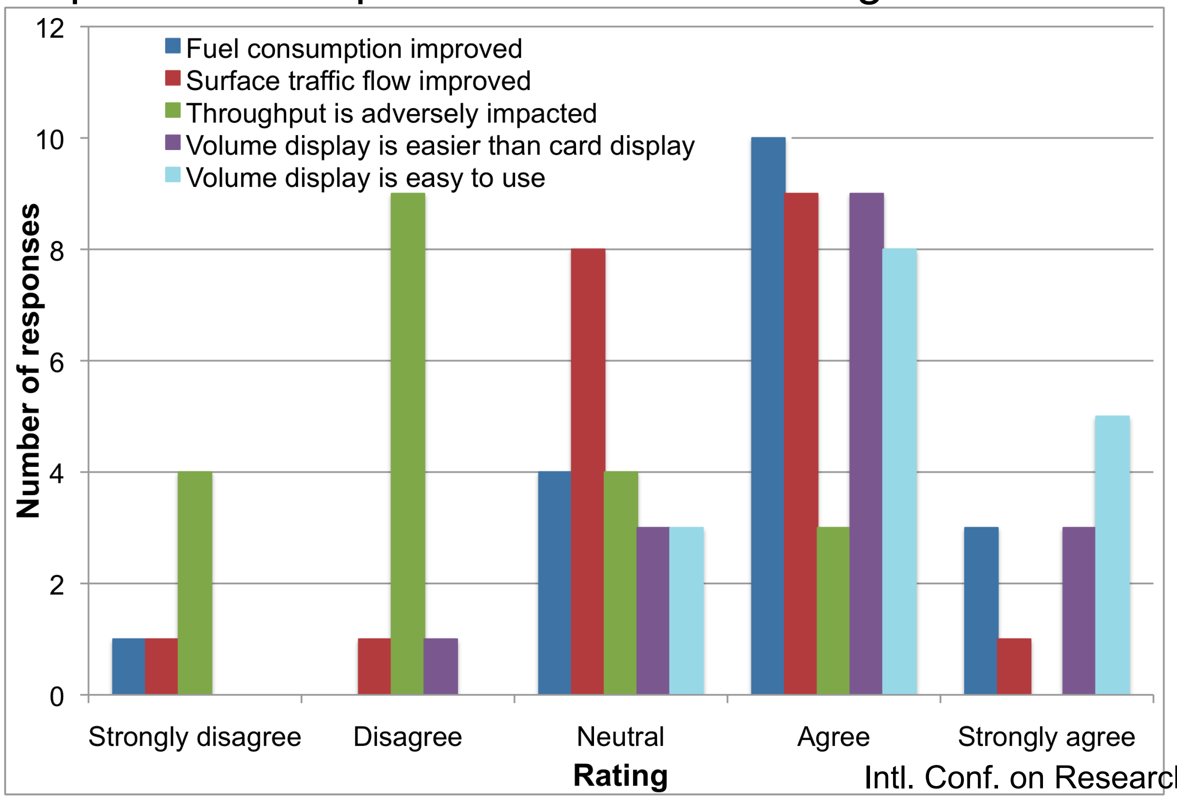




- Pushbacks in current time interval can be released (grayed out)
- Unused rate is carried over to the next time interval, up to 2/min
- Pushbacks in future time intervals can be reserved (angled)
- Pushbacks can be reserved for the following 15-min time period

Incorporating humans into control

- Survey of BOS controllers
  - 21 respondents: 15 (BOS Gate 2010), 13 (2011), and 12 (both)
  - General support: “the ability to touch planes,” “reserve spots,” “…count the planes and account for aircraft with long delays,” “allows me to push & tells me to hold,” and “easy to use & understand”
  - Responses were positive about combining BOS Gate & another position



Simaiakis et al., Intl. Conf. on Research in Air Transportation, 2012.

BOS field-test results

- Aug-Sep`10 & Jul-Aug`11
- 4PM-8PM departure push
- Average gate-hold: 4.7 min
- 23-25 tons (6,600-7,300 gal) reduction in fuel burn
- 52-58 kg decrease in fuel burn / gate-held flight
- 71-79 tons CO_2 reduction
- Fair distribution of benefits
- 1 min gate-hold => 1 min of taxi-out time savings
- Positive stakeholder feedback
  - Traffic managers noted improved surface "flows"

Configuration	# gate holds	Taxi-out time savings (min)
27, 22L | 22R	63	256
27, 32 | 33L	34	114
27, 32 | 33L	8	38
27, 22L | 22R	45	295
27, 22L | 22R	19	42
27, 22L | 22R	11	23
27, 32 | 33L	11	24
27, 32 | 33L	56	210
2010	**247**	**1003 min = 16.7 hours**
27, 22L | 22R	14	28
27, 22L | 22R	42	384
27, 22L | 22R	50	290
4L,4R |4L,4R,9	11	13
4L,4R |4L,4R,9	7	13
27, 22L | 22R	6	9
27, 22L | 22R	12	23
2011	**142**	**760 min = 12.7 hours**

Key challenges

- Designing control strategies
  - Data-driven modeling
- Implementation/field-testing
- Interfacing with humans
- Evaluation/performance tracking/**metrics**
- Important to consider tradeoffs/interactions
- **Situational awareness is important, but does not equal decision-support!**
- Need graceful degradation in case of automation failure
  - "Business-as-usual" may not be feasible fall-back option