Efficient Aircraft Assignment for Search and Rescue of Threatened Population in Disaster Relief Operations

Adriana Andreeva-Mori
Aeronautical Technology Directorate
Japan Aerospace Exploration Agency

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Outline: JAXA’s system for disaster relief

• Disaster relief
  – Efficient reconnaissance
  – Prompt planning and execution of rescue missions

• JAXA’s integrated aircraft operation system for disaster relief (D-NET 2)
  – Satellites
  – Manned aircraft
  – Unmanned aircraft

DIRECT
Search & Rescue

Collaboration with direct participants in disaster relief
Collaboration

Research
- Other projects (e.g. Kyoto University)
- AIST
- ENRI, Hokkaido Broadcasting
- Weathernews

Incl. Satellites, UAVs
- Disaster information
- Image processing
- Obstacle detection
- Small aircraft operation information

Verification & Evaluation
- Cabinet Office
- FDMA Municipal Fire Services
- MHLW DMAT
- Self Defense Forces
- Japan Coast Guard
- AJATS
- JCAB CARATS

Development
- Avionics manufacturer (Navicom Aviation)
- IT, software developers (VRTC, MSS)
- Aircraft manufacturer (KHI)
- Aircraft maintenance (CHS)

AIST: National Institute of Advanced Industrial Science and Technology
AJATS: All Japan Air Transport and Service Association
CARATS: Collaborative Actions for Renovation of Air Traffic Systems
CHS: Central Helicopter Service
DMAT: Japan Disaster Medical Assistance Team
ENRI: Electronic Navigation Research Institute
FDMA: Fire and Disaster Management Agency
JCAB: Japan Civil Aviation Bureau
KHI: Kawasaki Heavy Industries
MHLW: Ministry of Health, Labour and Welfare
MSS: Mitsubishi Space Software
VRTC: VR Techno Center

: established
: to be finalized
: in FY2015
System properties and requirements

- Enable safe and efficient operations
- Test concepts and strategies
- Demonstrate operations
  - Numerical simulations
  - Disaster drills
- Require partnerships
  - Fire departments
  - Disaster medical assistance teams
  - Industry
- Predict and manage congestions
- Handle heterogeneous vehicles
Search and rescue flow

Search (reconnaissance) → rescue → logistics, road reconstruction, etc.

QOL=1 unknown
QOL=2 life in danger
QOL=3 emergency goods needed
QOL=4 full recovery

right after the earthquake (March 11, 14:46)
16 h later (March 12, 6:46)
20 h later (March 12, 10:46)

*QOL: Quality of Life
Current research scope

Main constraints

- Hard time limit $t_{lim} = 72$ h
- Aircraft performance constraints
- Total number of aircraft
I. The best general resource distribution?
II. Resources vs. necessary time
III. Sufficient resources?
Simulation assumptions (preliminary)

- Iwate Prefecture (2\textsuperscript{nd} largest in Japan, 15,280 km\textsuperscript{2})
- Manned aircraft only
- One helicopter base
- Continuous operations (72 h → 42 h)
- Available aircraft
- Aircraft operational constraints
  - Maximum fuel constraint (flight range 2.5 h - 3.5 h)
  - Refuel time 20 (30) min
  - Passengers capacity: 5, 14, 25

Resource Distribution

Disaster Operational time 72H

Base

High-risk areas

50 medium

2 large + 5 small

Resource Distribution

Reconnaissance

(\textit{Search})

Rescue

(\textit{Rescue, Fire extinguishing, Transportation of personnel and goods})
Simulation cases

I. Search aircraft 50 → 40 ... 10

II. Search aircraft 50 (const)

Goal

- Search the whole disaster area ASAP
- Transport all evacuees to the base ASAP
II. Search aircraft 50 (const)

- Cluster-based algorithm
- Adjustments for operational constraints
- Cell priority!
- Flight routes also generated
- Very fast computation (less than a minute)
- Routes might vary, but reconnaissance time is robust
  → strategic planning
**QOL=1.5**

Search (reconnaissance) → rescue → logistics, road reconstruction, etc.

1. Needs located
2. Helicopter lands at the site
3. No immediate action needed

Output:
- Number of evacuees, state, etc.
- QOL needs defined

QOL=1 unknown
QOL=2 life in danger
QOL=3 emergency goods needed
QOL=4 full recovery

Number of grids found where rescue is needed (Total: 69)

Operational time (start = 0 h) [h]
Cells with number of evacuees known

QOL=1
- Search/transport
QOL=2
- Life in danger
QOL=3
- Emergency
QOL=4
- Full recovery

Search (reconnaissance)
Logistics, road
Helicopters
QOL=2
7 rescue aircraft
7+10 rescue aircraft

1. Needs located
2. Needs defined
Output: Number of evacuees, state, etc.

3. Helicopters rescue evacuees
   (reconnaissance)
   No
   Yes
   needs?
   Immediate
   action needed
   search
   (reconnaissance)
   Helicopter
   lands at the site
   3
   Helicopters
   rescue evacuees
   QOL=2
Search (reconnaissance) rescue reconstruction, etc.

QOL=1 unknown
QOL=2 life in danger
QOL=3 emergency goods needed
QOL=4 full recovery

1 Needs located
2 Needs defined
3 No immediate action needed

Output:
- Number of evacuees, state, etc.
- QOL=3

7 rescue aircraft
7 + 10 rescue aircraft
7 + 20 rescue aircraft

Operational time (start = 0) [h]
Result Analysis

- In reality, less than 50 search aircraft
  - UAV can be the key

- Accurate prediction of needs location
  - “uncertainties” considered in new simulation

- Resource allocation curve is more complicated than expected
  - Dependence on disaster scenario
  - More scenarios being considered

- Multi-objective optimization
Conclusions

- Overall estimation of search and rescue time
- Successful aircraft assignment
- Fast real-time simulation → strategic planning
- New insights into resource allocation

Future work

- More practical constraints
- Other scenarios
- Uncertainties
- Multi-objective optimization (Pareto solution)