ABOUT THE SPEAKER

- PhD in Theoretical Computer Sciences (2011)
- Live and work in Moscow, Russia
- Institute for Systems Analysis of Russian Academy of Sciences
- Research interests: Artificial Intelligence, Heuristic Search, Path Planning, Robotics
- Current research focus: computationally effective control system for small-scale unmanned aerial vehicles
  - Path-planning methods and techniques
OUTLINE

1. Unmanned vehicles variety (our scope: vertical take-off and landing unmanned aerial vehicles)

2. Intelligent control systems for VTOL UAVS

3. Methods and models needed to build an ICS
REFERENCES

- **Images**
  - “google images”, images from below-mentioned papers, ISA RAS images, author’s images.

- **Papers**

- **Web-sites**
  - www.isa.ru
  - www.ai-uv.ru
  - www.raai.ru
UNMANNED VEHICLES VARIETY
UNMANNED VEHICLES
OUR SCOPE: VTOL UAV

Vertical take-off and landing unmanned aerial vehicles
CATEGORIES OF VTOL UAVS

Category I: full-scale unmanned helicopters or optionally-piloted autonomous helicopters.

Category II: medium-scale UAS helicopters that are available as autonomous or semi-autonomous platforms and have significant payload (more than 10 kg) with a total weight of more than 30 kilograms.

Category III: small-scale RUAS which are based on RC-helicopters with optionally-integrated autopilot. They have a payload of several kilograms (2 kg to 10 kg) and a total weight of less than 30 kilograms.

Category IV: this category includes mini rotorcraft UAS that are man-portable and can fly outdoors as well as in confined and indoor environments. Their payload is generally less than 2 kg and their total weight can range from hundreds of grams to a few kilograms.

Category V: this last category includes micro air vehicles (MAVs) with less than 100 grams payload, such as the Epson micro flying robot. Standard navigation sensors and avionics are difficult to carry on these machines.
CATEGORIES OF VTOL UAVS

Class I: Piasecki/CMU optionally piloted autonomous helicopter (Boeing Unmanned Little Bird)

Class II: NASA/Army autonomous rotorcraft UAS (Yamaha RMAX)

Class III: the CSIRO-ARCAA robotic helicopter (VARIO Benzin Trainer)

Class IV: the MIT autonomous indoor quadrotor (Ascending Technologies)

Class V: the Epson micro-flying robot
INTELLIGENT CONTROL SYSTEMS for VTOL UAVS
**UNMANNED VS AUTONOMOUS**

unmanned ≠ autonomous

unmanned + ??? = autonomous (to a certain degree)

??? – intelligent control system (artificial intelligence)

autonomy degree – complicated thing
It really IS complicated
INTELLIGENT CONTROL SYSTEM

- **Architecture** (conceptual, software modules, data exchange protocols etc.)

- **Methods** and algorithms
ICS ARCHITECTURE: FUNCTIONAL DECOMPOSITION

- **Mission Planning** – develops plans for the team and for individual vehicles
- **Collaboration** – manages team formation and interaction among team members
- **Contingency Management** – detects, assesses, and responds to unexpected events
- **Situational Awareness** – creates Common Relevant Operating Picture (CROP)
- **Communications Management**
- **Air Vehicle Management** – Manages the air vehicle’s flight systems, sensors, and weapons.
- **Resource Meta-Controller** – Manages processing resources and dynamically allocates them to different components as necessary.
ICS ARCHITECTURE: FUNCTIONAL DECOMPOSITION

GNC

- Guidance
- Navigation
- Control

KONSTANTIN YAKOVLEV, YAKOVLEV@ISA.RU, ROBOTICS EXPO 2014 (ROBOTICS CONFERENCE), 27 NOVEMBER 2014
ABSTRACT FUNCTIONAL DECOMPOSITION APPROACH: 4D/RCS REFERENCE MODEL ARCHITECTURE
4D/RCS: MULTILAYERED APPROACH

Battalion
- Battalion HQ

Company
- Artillery
- Armor
- Logistics

Platoon
- IndirectFire
- DirectFire
- AntiAir

Section
- UAV C2
- Manned C2
- UGS C2

Vehicle
- UAV
- UARV
- UGV Scout

Subsystem
- RSTA
- Communications
- Weapons
- Mobility

Primitive
- Gaze
- Select
- Driver

Servo
- Pan
- Tilt
- Iris
- Focus
- Speed
- Heading

Sensors and Actuators

24 hr plans replan every 2 hr
5 hr plans replan every 25 min
1 hr plans replan every 5 min
10 min plans replan every 1 min
1 min plans replan every 5 s
5 s plans replan every 500 ms
500 ms plans replan every 50 ms
50 ms plans output every 5 ms
ISA RAS ARCHITECTURE

Architecture is developed within the Russian Science Fund project #14-11-00692
METHODS AND MODELS

needed to build an ICS
FLIGHT CONTROL
STATE (POSE) ESTIMATION
SIMULTANEOUS LOCALIZATION AND MAPPING
GUIDANCE

Path Planning
- RoadMaps (RM)
- Potential Fields (PF)
- Heuristic Search Algorithms (HSA)
- Optimization Methods (OM)
- Planning Under Uncertainties (PUU)
- Reactive and Bio-Inspired Obstacle Avoidance Methods (RBIOAM)

GUIDANCE SYSTEMS

Mission Planning
- Description of mission planning systems developed by NASA, ONERA, DLR and UASTech

Multi-RUAS Cooperation
- Coordinated flight control
- Cooperative perception
- Cooperative mission planning and decision-making
DELIBERATIVE PATH PLANNING

1. Flight simulation + search

2. Estimating “geometry constraints” using UAV model, then – search within constraints
SUMMARY

Active research topics (unsolved problems)

- Architecture of the intelligent control systems
  - Functional decomposition
  - Multilevel decomposition
  - Interaction between modules/levels
  - Standardization

- Methods and models needed to develop ICS
  - Accurate models of VTOL UAVs
  - Vision based SLAM (especially monocular SLAM)
  - Path planning under constraints
  - Mission planning
  - Multi-agent cooperation
FEW ANNOUNCEMENTS
WORKSHOP “ARTIFICIAL INTELLIGENCE AND UNMANNED VEHICLES”

www.ai-uv.ru

Central meeting point for researchers from 2 domains: Artificial Intelligence and Unmanned vehicles

1st workshop took place in Kazan, Russia, September 24

16 speakers from top research centers and universities from all over Russia, more than 150 attendees

Accepted papers were published in the proceedings of National Russian Conference on Artificial Intelligence

2nd workshop is planned to be held in Saint-Petersburg, Russia, October 2015

We welcome all researchers to take part in the 2015 workshop

contact person: Konstantin Yakovlev, yakovlev@isa.ru
AI-DRONE

AI-Drone – an initiative young scientists (students, PhD students, etc) project aimed at developing state-of-the-art intelligent control system for small unmanned quadrotor

Finalist of CROC-2013 “Fly away and back” contest

We use Ar.Drone as a platform, ROS as a framework

We focus on:
- visual pose estimation (visual odometry)
- visual SLAM
- objects of interest recognition

We welcome enthusiastic young people with strong academic background, coding skills and basic English to take part in the project

contact person: Konstantin Yakovlev, yakovlev@isa.ru
QUESTIONS?

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