Goals

- Unmanned Aerial Vehicle (UAV) technology is maturing
  - UAVs are ready for autonomous missions technically
    - Surveillance, firefighting, agriculture, etc.
  - Autonomous missions are not authorized
    - Missing redundancy
    - Missing collision avoidance device
      - Automatic collision avoidance device is needed even for remotely piloted UAVs
- Remote aircraft detector sensor development is introduced in this presentation
  - "When Will We Have Unmanned Commercial Airliners?"
  - IEEE Spectrum Magazine
  - December 2011

Sense and avoid – key issue

Outline

- Goals
  - Sense and avoid problem
- System requirements
- Closed loop visual SAA system
- Vision system architecture
- Algorithms
- Many core processor array implementation

Requirements

- Detect a 10m aircraft from 2km
- 0.1 degree/pixel resolution
- min. 220x60° view angle
- Flyable size/weight/power figures (@25Hz, <1W, <500g)
- On-board data storage

Closed loop SAA system

HIL simulator

Camera selection

- Single camera with wide angle optics
  - Easy from architectural, algorithmic, and processing side
  - Low distortion, ultra wide view angle optics are bulky
- 3 pieces of C-mount cameras
  - Good image quality
  - Relatively large size, volume, and power (1kg, 10W)
  - High speed serial I/O (USB, Gige, firewire) difficult to connect to embedded systems
- 5 pieces of miniature cameras (M12 lens)
  - Max 1.2 megapixel with global shutter
  - 50g, 200mW
  - Poorer image quality
- Micro cameras
  - Very advantageous size/weight/power figures
  - Rolling shutter only

Architecture

- High resolution camera system in the visual range
  - Elongated, (220x60°)
  - Large view angle
  - min 2MPixel
- FPGA processing system
  - High computational power
  - Low power consumption
- Solid state disk
  - Bandwidth
  - Capacity
  - Vibration

Collision avoidance devices

- Radar based
  - Applied on large airliners (Airbus)
- Radar and vision
  - Applied on large remotely piloted UAVs (predator)
- Transponder based
  - TCAS, ADS-B (all manned aircrafts and larger UAVs)
- Vision only
  - Currently developed (small UAVs)
- Basic requirements
  - Equivalent safety
  - Probabilities of collision < 10^-11 per flight hour
  - Layered approach
Sensor and computational system
- 5 pieces of wVGA micro cameras
  - Aptina MBSV034 sensor
  - 5g
  - <150mW
  - 3.8mm megapixel objectives (M-12)
  - 70 degrees between two cameras
  - Total view angle: 220° x 78°
- FPGA board with Spartan 6 FPGA
- Solid State Drive (128Gbyte)

Mechanics
- Stable camera holder
  - Alignment
  - Avoids cross vibration of the cameras
  - 100g
  - Aluminum alloy
  - Electronics in the middle
  - Covered with aluminum plates

Hardware system
- Sensing and processing system
  - Field of view: 220° x 78°
  - Resolution: 2250x752
  - Frame-rate: 56 FPS
  - Processor: Spartan6 L45 FPGA
  - Storage: 128Gbyte (23 min)
  - Size: 125x145x45mm
  - Weight: ~450g (~1lb)
  - Power consumption: <8W

Vision system mounted to the airplane

View angle

Algorithmic components
- Aircraft detection against sky background
  - Preprocessing on the full frame
  - Identifying candidate points
  - Post processing
  - Discarding non-relevant candidate points
  - Tracking
  - Multi-level global and local adaptivity
- Aircraft detection against terrain background
  - Visual-inertial data fusion
  - Motion based moving object detection

Detection against the blue sky

Preprocessing (full frame)
- Identifies the candidate aerial objects
- Finds numerous false targets also
- Local adaptation based on edge density
- Global adaptation based on number of candidate points

Preprocessing (full frame)
- Identifies the candidate aerial objects
- Finds numerous false targets also
- Local adaptation based on edge density
- Global adaptation based on number of candidate points
Post processing (ROIs)

- Discard edges of clouds
- Significantly reduces the number of candidate points
- Resulting few targets can be tracked

- Cutting the perimeter of each object
- Histogram calculation
- Accept candidate point
- Reject candidate point
- Variance high?

Tracking on image plane

- Candidate objects:
  - Separate objects
  - Track objects
- Filtering according to:
  - Velocity, acceleration
- InstantVision™ 4.1 Multitarget Tracking Library (Eutecus Inc.)

Example 1: Ground camera in hand

Example: Airborne camera

Pre- and post processing

Red points: all candidate objects
Green point: allowed by post processing

Pre- and post processing + tracking

Red points: all candidate objects
Green points: allowed by post processing
Blue points: tracked objects
Many-core processor arrays implemented in FPGA

- FPGA chips have the largest computational capability nowadays
- In affordable medium size FPGAs:
  - Over 200 DSP cores
  - 200 memory blocks
  - 500 I/O pins
  - Low power consumption
- Special purpose processor arrays
- How to utilize this performance?
  - Many-core architectures
  - Specially optimized data and control paths
  - Distributed control units

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