LTA-UAV: The Future of Disaster Response and Surveillance

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Presentation Outline

Background and why UAV

LAT-UAV

Object Tracking

Future

Surveillance phase and service description

The rational behind drone (in border surveillance)

Surveillance phase and service description

The rational behind drone (in border surveillance)
Smuggle diesel at Malaysia Thai border

Thai authorities in the border towns have detected a rise in the smuggling of petrol and diesel from Malaysia following a sharp increase in domestic fuel prices in Thailand.
Border Surveillance

- Some months ago, Malaysia found ‘migrant’ mass graves near

The several mass graves thought to contain bodies of migrants have been found in Malaysia, the graves were found in 17 abandoned trafficking camps near the Thai border. Every year thousands of people are trafficked through Thailand into Malaysia.
Why do we need an Malaysia Costal Patrol & Border Surveillance system?

Long Coastline Border

Real time surveillance

To prevent any event before occurring

UAV Technology is now fully mature and ready to be placed instead very costly using aircraft and coastal Patrol boats
Border Surveillance Framework

Thick arrows represent sensor or information data, and thin arrows represent control signals.
Five basic steps for Border Surveillance

1. Collect multitemporal imagery using specific techniques
2. Spatially co-register the multitemporal images
3. Perform change detection to identify features of interest
4. Collect geographic coordinate information
5. Transmit the locations of change features of interest

Border surveillance
Surveillance phases and service description

- Depending on the area (maritime/land) the surveillance activities can be grouped in distinct progressive phases based on the following three levels:

<table>
<thead>
<tr>
<th>What is it</th>
<th>Strategic level</th>
<th>Operational level</th>
<th>Tactical level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Pertaining to the planning of sequences of operations, the resources needed for the operations, and the collection and analysis of information needed to make that planning.</td>
<td>Pertaining to the planning and running of operations. An operation is a sequence of actions in a pre-planned framework of assets, personnel and time.</td>
<td>Pertaining to executing the elements of an operation, choosing the elementary actions and reactions in (almost) real time – or as close to real time as possible.</td>
<td></td>
</tr>
<tr>
<td>Months to years</td>
<td>Weeks to months</td>
<td>Hours to days</td>
<td></td>
</tr>
<tr>
<td>Typical timescale for planning ahead</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
# Surveillance phases and service description

<table>
<thead>
<tr>
<th></th>
<th>Strategic level</th>
<th>Operational level</th>
<th>Tactical level</th>
</tr>
</thead>
<tbody>
<tr>
<td>Shortest timescale to</td>
<td>Weeks. E.g., decision to start collecting information from a certain area.</td>
<td>Days. E.g., the decision to call off a planned operation, or to substitute one</td>
<td>Seconds (immediate). E.g., decision to apprehend persons, or save people from a</td>
</tr>
<tr>
<td>change plans</td>
<td></td>
<td>available asset by another.</td>
<td>boat in immediate danger.</td>
</tr>
<tr>
<td>Maximum allowed delay of</td>
<td>A month. E.g. statistics of arrivals and analysis of methods used by illegal</td>
<td>Days. E.g. information on the appearance of new tracks in the land border region,</td>
<td>Fraction of an hour. E.g. information about last sighting of a truck or a group</td>
</tr>
<tr>
<td>information</td>
<td>immigrants.</td>
<td>or information on boat arrivals in a new area.</td>
<td>of people, or locations of unknown boats.</td>
</tr>
<tr>
<td>Radius of interest</td>
<td>Semi-global</td>
<td>Region / basin</td>
<td>&lt; several 10 km</td>
</tr>
</tbody>
</table>

The same products may be used in each level, but in a different way. The level is primarily a property of the service, not of the product.
## Land Phases

<table>
<thead>
<tr>
<th>Phase 1</th>
<th>Phase 2</th>
<th>Phase 3</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Strategic Level</strong></td>
<td><strong>Strategic/ Operational level</strong></td>
<td><strong>Operational/ tactical level</strong></td>
</tr>
<tr>
<td>Static – reference maps (prerequisite for Phase 2)</td>
<td>Low-time critical – background changes</td>
<td>Punctual monitoring – volume/flux of actual crossings</td>
</tr>
</tbody>
</table>
a) This service include following functionalities:

- Obtain a reference situational picture on the topography, transport infrastructure, routes, hubs/nexus points, stopovers etc.

- Conduct change analysis by comparison to the reference picture on a regular basis to detect any changes;

- Detect or verify the routes potentially used by illegal migrants and smugglers of contraband and to adapt border control measures (patrols, deployment of surveillance infrastructure) accordingly;

- Gather further information expanding on intelligence (e.g. on gathering points; in situation of urgent and exceptional pressure at certain external land border sections as result of a political crisis, natural catastrophes);
b) Requirements:

Static:

- Enable mapping of terrain, including topography, land cover, buildings, roads, tracks, demarcations, etc., by virtue of adequate spatial resolution (horizontal and vertical), spectral power, etc.;

- Product must be ortho-rectified and terrain geo-coded, which implies that also a DEM at the proper resolution must be available;

- Geographic features should be in vector form in order to facilitate their automatic identification, selection and query;

- Data must be in such a form that they can be combined with existing maps used by the authorities (projection, datum, format, standards).
### Indicative Performance Requirements

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Optical</th>
<th>Radar</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Resolution</td>
<td>50 cm – 5 m</td>
<td>1 m – 50 m</td>
<td>Higher resolutions are classified. Lower resolutions are not used for surveillance.</td>
</tr>
<tr>
<td>Image Size</td>
<td>For the highest resolution, 10 x 10 km. For lower resolutions, up to 60 x 60 km.</td>
<td>For the highest resolution, 10x10 km. For lower resolutions, up to 400x400 km.</td>
<td>The higher the resolution, the smaller the image.</td>
</tr>
<tr>
<td>Tasking Time</td>
<td>Normal: 12h to days before overpass. Fast: asap to 12h before overpass.</td>
<td>Normal: several days ahead. Fast: 6 to 24 h ahead</td>
<td>Precise times vary per satellite operator. Orders at short notice are (much) more expensive.</td>
</tr>
</tbody>
</table>
## Indicative Performance Requirements

<table>
<thead>
<tr>
<th>Attribute</th>
<th>Optical</th>
<th>Radar</th>
<th>Remarks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Delivery Time (after image acquisition)</td>
<td>Normal: 1 day. Fast: few hours</td>
<td>Normal: up to 1 day. Fast: up to 30 min</td>
<td>Precise times vary per satellite operator. Very fast times can be obtained only for a few images, not for all. VHR data may be intentionally delayed on national security laws. Faster delivery is more expensive.</td>
</tr>
<tr>
<td>Processing and analysis time</td>
<td>Over land: Fast analysis: 1-3 hr. Full analysis: 1 day. Ship detection at sea: Fast analysis: 1 hr. Full analysis: 6 hr.</td>
<td>Over land: Fast analysis: 1-3 hr. Full analysis: 1 day. Ship detection at sea: Fast analysis: 30 min. Full analysis: 1h – 1h30 min.</td>
<td>The time depends on the area of interest within the image that needs to be analysed, the density of objects, the exact nature of the analysis, etc.</td>
</tr>
</tbody>
</table>
Static Reference Data

1. Satellite imagery (ortho-rectified and ortho-photo datasets)
2. Land-use datasets at medium (1:25 000) scale
3. Topographic Map at medium (1:25 000) scale
4. Digital Elevation Model (DEM)
5. Nautical Charts
6. Weather data
7. Reference Maps (geo-coded databases)

- Geo-referenced demographic profiles of populations.
- Geo-referenced database of socio-economic variables (databases containing information on migration push or pull factors such as unemployment, poverty, health, economic development,
- Geo-referenced database of population ethnicities/languages/religion etc.,
- Geo-referenced information on illicit activities (hotspots), smuggling routes and human-terrain analysis (including administrative info/jurisdictions).
## Optical Satellites

<table>
<thead>
<tr>
<th>Satellites</th>
<th>Spatial resolution (after pan-sharpening)</th>
<th>Frequency</th>
<th>Equator Crossing Time</th>
</tr>
</thead>
<tbody>
<tr>
<td>Worldview-4</td>
<td>0.31 m</td>
<td>&lt; 1.0 day</td>
<td>10.30 am</td>
</tr>
<tr>
<td>Worldview-3</td>
<td>0.31 m</td>
<td>&lt;1.0 day</td>
<td>10.30 am</td>
</tr>
<tr>
<td>Worldview-2</td>
<td>0.46 m</td>
<td>1.1 days</td>
<td>10.30 am</td>
</tr>
<tr>
<td>Worldview-1</td>
<td>0.46 m</td>
<td>1.7 days</td>
<td>10:30 am</td>
</tr>
<tr>
<td>GeoEye-1</td>
<td>0.46 m</td>
<td>2.1 days</td>
<td>10:30 am</td>
</tr>
<tr>
<td>Pleiades-1A</td>
<td>0.5 m</td>
<td>Daily</td>
<td>10.30 am</td>
</tr>
<tr>
<td>KOMPSAT-3A</td>
<td>0.55 m</td>
<td>Daily</td>
<td>10.30 am</td>
</tr>
<tr>
<td>KOMPSAT-3</td>
<td>0.7 m</td>
<td></td>
<td>10.30 am</td>
</tr>
<tr>
<td>QuickBird</td>
<td>0.65 m</td>
<td>1-3.5 days</td>
<td>10:30 am</td>
</tr>
<tr>
<td>Gaofen-2</td>
<td>0.8 m</td>
<td></td>
<td>10.30 am</td>
</tr>
<tr>
<td>TripleSat</td>
<td>0.8 m</td>
<td>daily</td>
<td>10:30 am local time</td>
</tr>
<tr>
<td>IKONOS</td>
<td>0.82 m</td>
<td>3 days</td>
<td>10:30 am solar time</td>
</tr>
<tr>
<td>SkySat-1</td>
<td>0.9 m</td>
<td></td>
<td>10.30 am</td>
</tr>
<tr>
<td>SkySat-2</td>
<td>0.9 m</td>
<td></td>
<td>10.30 am</td>
</tr>
<tr>
<td>SPOT-6</td>
<td>1.5 m</td>
<td></td>
<td>10.30 am</td>
</tr>
<tr>
<td>SPOT-7</td>
<td>1.5 m</td>
<td></td>
<td>10.30 am</td>
</tr>
<tr>
<td>Other Satellites</td>
<td>2 m-20 m</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
UAV for filling the Gap

- High resolution
- Lower cost
- More flexible
- Precise
- Real time
- Convenience
The rationale behind drones (in border surveillance)

- Costs: cheaper (?), calculated per h/flight (?)
- Autonomy (or remoteness) > rationalizing human resources
- High endurance (Nomad: > 10 h)
- Information/intelligence (ISTAR: intelligence, surveillance, target acquisition, reconnaissance)
- Increased surveillance > situational awareness > humanitarian
- Dimension: saving human lives at sea (political discourse, Commission)
UAS- Platform 1: Fixed Wing System

Airframe / Autopilot

Radio Control

Telemetry system

Ground Control

Camera

Post Processing
Platform 2: Multirotor System

Radio Control

Airframe / Autopilot

Camera

Telemetry system

Ground Control

Post Processing
NOMAD-X is a complete airborne multi-mission unmanned aircraft measuring 3 metres tip to tip. Designed with a large internal bay enabling it to carry up to 6 kg of payload. Having an extended endurance of 4 hours makes this UAV unmatched in its class.
• The unique design of the NOMAD-X allows for fast setup and mission start in the field. Coupled with a generous payload carrying capacity, extended endurance and reliability makes this system truly a multi-mission UAS.

• Take-off is easily accomplished by hand or catapult launcher. Landing is autonomous and can be a belly landing or flown into an erected landing net for use in confined areas.
NOMAD-X

Platform Characteristics:

Airframe material: Composite (CF/FG)
Propulsion: Electric
Maximum take off weight: 8 kg
Empty weight: 2 kg
Wingspan: 3000 mm
Fuselage length: 1100 mm
Cruise speed: 15 m/s (29 kts)
Dash speed: 34 m/s (66 kts)
Maximum wind penetration: 18 m/s (35 kts)
Command & Control range: 40 km (900 Mhz)
Data-link range: 20 km (1.3Ghz)
Long range communications: 3G / 4G / LTE / IRIDIUM
Platform 4: Lighter-than-Air Unmanned Aerial Vehicle (LTA-UAV)

Refers to aerial vehicle that

– Generates all or a fraction of its lift using gases e.g. helium or hydrogen

– Operates without pilot, either under remote control or full-autonomously by an onboard computer

– Examples: airship, hybrid airship, high-altitude balloon
Potentials of LTA-UAV

- Maneuver and remain in a desired geographic location for days/weeks ("station-keeping")
- Operates in higher altitudes (10-40 km)
- Provide surveillance over large areas
- A fraction of the cost of a satellite

A platform for persistent, hi-resolution, local- to regional-scale observation
LTA-UAV Operating Altitude Capability
Station-Keeping and High-Altitude Observation
Free-floating Balloon vs HTA (Glider) vs LTA

Photo credit: Courtesy graphic https://www.army.mil/article/62316
Persistent Surveillance & Wide-area Motion Imagery

Graham Warwick, Aviation Week & Space Technology, Defense & Space Technologies to Watch in 2016
Comparison with other Surveillance Options

### Multicopter
- **Altitude:** up to 700 m
- **Coverage:** Small
- **Cost:** Low
- **Maneuver:** Flexible & Narrow
- **Concern:** Battery, Weather

### Balloon/Airship
- **Altitude:** 10km-40km
- **Coverage:** Large
- **Cost & Usage:** Medium
- **Maneuver:** Persistent
- **Concern:** Helium, maneuverability (wind)

### Airplane/Heli
- **Altitude:** 50-3500 m
- **Coverage:** Large
- **Cost & Usage:** High
- **Maneuver:** Flexible, semi-persistent
- **Concern:** Fuel, High-risk (Manned)

### Satellite
- **Altitude:** 160-500 km
- **Coverage:** Very large, global
- **Cost & Usage:** High
- **Maneuver:** Fixed path, non-persistent
- **Concern:** Cloud, frequency of revisit
Resolution-Coverage Spatial-Temporal

<table>
<thead>
<tr>
<th></th>
<th>RESOLUTION</th>
<th>COVERAGE</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>LTA-UAV</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SPATIAL</strong></td>
<td>High</td>
<td>Local to regional</td>
</tr>
<tr>
<td><strong>TEMPORAL</strong></td>
<td>High</td>
<td>Diurnal to seasonal</td>
</tr>
<tr>
<td><strong>Aircraft</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SPATIAL</strong></td>
<td>Moderate</td>
<td>Global</td>
</tr>
<tr>
<td><strong>TEMPORAL</strong></td>
<td>Low</td>
<td>Weekly to inter annual</td>
</tr>
<tr>
<td><strong>LEO Satellite</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SPATIAL</strong></td>
<td>High</td>
<td>Regional to continental</td>
</tr>
<tr>
<td><strong>TEMPORAL</strong></td>
<td>Low</td>
<td>Seasonal to inter annual</td>
</tr>
<tr>
<td><strong>GEO Satellite</strong></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>SPATIAL</strong></td>
<td>Low</td>
<td>Continental to 3rd of sphere</td>
</tr>
<tr>
<td><strong>TEMPORAL</strong></td>
<td>High</td>
<td>Diurnal to inter annual</td>
</tr>
</tbody>
</table>
Most Promising Use Cases for **LTA-UAV** in Disaster Relief

- **Emergency Locator Beacon**
- **Post-disaster assessment**
- **Communication & Broadcast**
- **Heavy-lift land anywhere**
Lighter-than-Air UAV Applications

High-Altitude

LTA-UAV

Lighter-than-Air
Unmanned Aerial Vehicle

Weather

Disaster

Agriculture
LTA UAV or Platform Potential Missions

Megacity Carbon Emissions Observation
Duren and Miller (2012)

- FOV: \(>10^5 \text{ km}^2\)
- Spatial resolution: \(<10 \text{ m}\)
- Duration: days
- Frequency: monthly

Coastal Ecosystem Monitoring

- FOV: \(>10^5 \text{ km}^2\)
- Spatial resolution: \(<10 \text{ m}\)
- Duration: days
- Frequency: monthly
LTA UAV or Platform Potential Missions

Tropical wildlife monitoring

- FOV: $<10^2 \text{ km}^2$
- Spatial resolution: $<1 \text{ m}$
- Duration: days
- Frequency: seasonal

Persistent Surveillance – Cities/Ports

- FOV: $<10^2 \text{ km}^2$
- Spatial resolution: $<1 \text{ m}$
- Duration: hours
- Frequency: daily
LTA Vehicles : Current Development of Hybrid Airship

Nimbus EosXi  
NIMBUS Srl  
Italy

Hybrid Airship UAV  
Dept. of Aerospace Engineering  
UPM

P-791  
Lockheed Martin
LTA Platforms: Stratospheric Sounding

Zero Pressure Balloon

Space Balloon (@altitude 37 km)
Dept. of Aerospace Engineering
UPM

Super Pressure Balloon
NASA
AeroPutra Space HAB Project [3rd Launch]
Lighter-than-Air Unmanned Aerial Vehicle (LTA-UAV) Components:

Three (3) major systems are at the heart of every UAS and these are:

a) the Flight Management System (FMS),
b) the Power Plant (PP) and
c) the Data Acquisition System (DA).
Engineering Challenges

• **Aerospace Engineering** - flight control; LTA-UAVs are very susceptible to wind disturbances. Various ways of *tethering* are considered.

• **Structural & Manufacturing** - Manufacturing large rigid and semi-rigid airship

• Requires **large space** for storage, airport

• **Data Acquisition** : Sensors and real time data transmission

• **Data Processing and Machine Learning** : real time

• **Sustainability** - Helium is expensive and not renewable, while hydrogen storage and fueling is trickier.
Object Tracking
Allows you to designated a region of interest on the video as a target. The gimbal automatically steers to keep the object center of frame throughout platform movements. The template matching algorithm allows you to track objects even if they are partially obscured.

Motion Detection
You can follow multiple cars travelling on a road-will automatically tag up to 5 moving object within its FOV
Object Tracking

- Track an object (or multiple objects) over a sequence of images.
- Tracking is usually performed in the context of higher-level applications that require the location and/or shape of the object in every frame.
## Common Algorithms for Object Detection

<table>
<thead>
<tr>
<th>Object detection methods</th>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
</table>
| Optical flow             | ✓ it can work even in the presence of camera motion | ✓ sensitive to illumination changes and noise.  
  ✓ often can only detect partial edge shapes of moving objects.  
  ✓ computationally complex. |
| Temporal differencing    | ✓ The algorithm is simple and can quickly detect motion object while it appears.  
  ✓ adaptive to dynamic environments | ✓ unable to detect all relevant pixels and complete shapes of foreground objects.  
  ✓ small changes in object movements or stopping objects can cause temporal differencing to fail |
| Background subtraction   | ✓ flexible and fast  
  ✓ Low memory requirement  
  ✓ its computational simplicity | ✓ camera vibration and speckle noise also seriously affects the accuracy of detection  
  ✓ background scenes need to be consistent while the camera should also be fixed. |
Method (Object tracking)
Method (Object tracking)
Results

Detection and tracking of a multiple dynamic object
Methodology (Moving Object Detection)
Results: Multiple moving object detection

Illustrative examples of the DARPA VIVID dataset. The represented images of EgTest01, EgTest02, and EgTest03 are depicted in the first, second, and third columns, respectively.
Final Observation

- Costs: how cheap/expensive are drones?
- Process: technology-driven (democracy replaced by technocracy?)
- De-humanizing border surveillance, if unconnected from S.A.R. (vs: surveillance: epystemic bridging?)
- Increased surveillance > increased control (duties?) and increased situational awareness >
- Transparency: information will be partially classified.
TERIMA KASIH/THANK YOU
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