Image Processing on Aerial Platforms
• Imaging Systems Overview
• Imaging Sensor Processing Cycle
• Challenges on Aerial Platform based Image Processing
• Vision and Roadmap
Imaging Systems Overview
Chronological Timeline of Image Systems in MilSOFT

2005
- Algorithm Design
- Conceptual Design
- Photogrametry alg.
- Detection alg.

2010
- R&D Projects
- New Algorithms
- New Sensor Types
- Exploitation Platform

2012
- GIS Based System Design
- Data Unification
- Sensor Fusion

2014
- Mature Products
- Machine Learning

2018
- New R&D projects
- Integration to new projects
Intelligence and Surveillance Platform Overview

**TACTICAL LEVEL**
- EXTERNAL DATA INTEGRATION
- IMAGING SENSOR ACQUISITION
- AUXILIARY SENSOR INTEGRATION

**OPERATIONAL LEVEL**
- QUERY & ACCESS & ANALYZE
- PROCESSING & FUSION & DISSEMINATION
- TARGET MANAGEMENT AND INTELLIGENCE LIFECYCLE

**STRATEGIC LEVEL**
- CENTRALIZED INTEL DIRECTIONS & MANAGEMENT
• Different type of platforms and sensors are used for image processing

  • Unmanned Air Platforms
    • EO/IR Video Camera
    • Synthetic Aperture Radar
    • Platform Telemetry
  
  • Aircraft Platforms
    • Reconnaissance Pods
    • Platform Telemetry
  
  • City Surveillance Cameras
    • EO/IR Video
  
  • Satellite Platforms
    • Large Scale map data support
    • Photogrammetric capabilities
Application Layers in Image Processing

- **Application Layers**
  - **Sensor**
    - Video
    - SAR
    - Hyperspectral
    - Multispectral
  - **Data Set**
    - Hand-made
    - Commercial of the Shelf
    - Open Source
    - Provided by Customer
  - **Algorithm & Software**
    - Computer Vision
    - Machine Learning
    - Photogrametry
  - **Customer Projects**
    - R&D
    - Commercial Products
Imaging Sensor Processing Cycle
Image Processing Cycle

- Super Resolution
- Noise Reduction

- Mosaicing
- DEM Extraction
- Orthographic Correction

- Urban Area Detection
- Restricted Area Trespassing
- Change Detection

- Moving Target Indication
- Object Detection
Fusion
Detection and Tracking
Detection and Tracking

Image → Pre-Processing → Emissivity / Temperature Separation → Region Detection → Final Detections
Analysis
Challenges on Aerial Platform based Image Processing
Sensor Characteristics on Aerial Platforms

- Platform Movement
  - Multi Dimensional Movement
    - Platform Alignment
    - Sensor Alignment
  - Bumps and shakes during data acquisition
    - Wind
    - Platform Internal Components
      - Engine
      - Gimbal Units
Sensor Characteristics on Aerial Platforms

- Platform Movement
  - Multi Dimensional Movement $\Rightarrow$ Complex Motion Model
    - Platform Alignment
    - Sensor Alignment
  - Bumps and shakes during data acquisition $\Rightarrow$ Stabilization
    - Wind
    - Platform Internal Components
      - Engine
      - Gimbal Units
Sensor Characteristics on Aerial Platforms

• Altitude
  • High: Highest Stability, Small Targets
  • Medium: Medium Stability, Medium Size Targets
  • Low: Low level stability, Large Size Targets

• Climatic
  • Clouds
  • Changes in the lighting conditions

• View target in oblique angles with long distances
• Elevational variations due to earth geoid surface
Sensor Characteristics on Aerial Platforms

- **Altitude** => Specific algorithms for each altitude
  - High: Highest Stability, Small Targets
  - Medium: Medium Stability, Medium Size Targets
  - Low: Low level stability, Large Size Targets
- **Climation** => Filtering and light compensation
  - Clouds
  - Changes in the lighting conditions
- **View target in oblique angles with long distances**
- **Elevational variations due to earth geoid surface**
  - => Angular correction and orthographical correction
Deep Learning and Sensor Characteristics

- Altitude
- Climation
- Oblique Angles

- Learning objects in different scales
- Augment data which imitating imaging sensor acquisition characteristics due to climate changes
- Flexible target detection in terms of acquisition from different angles

- It is possible to design an algorithm which manages to tackle all the problems of multiple computer vision algorithms. But;
  - Complexity
  - Data Set
  - Processing Power
  - Theoretical Limits
Deep Learning and Sensor Characteristics

- Mostly used deep learning architecture:
  - Convolutional Neural Networks

- Training:
  - Data Augmentation is a must
    - Images from different perspectives
    - Images from different angles
    - Images taken in cloudy/rainy weather
    - Physical dirtiness on the sensor

- Inference:
  - Limited processing resources (cpu and memory)
  - Neural network quantization (performance vs. accuracy trade-off)
Challenges in Development Cycle

• Variety of data types vs data context difference
  • «Site environment» / «Development environment» difference
  • Realistic Synthetic Data Production

• Algorithms as viable products
  • Used in different hardwares
  • Used in different operating environments
  • Used with different sensor models
Challenges in Development Cycle

• Variety of data types vs data context difference
  • «Site environment» / «Development environment» difference
  • Realistic Synthetic Data Production
• Test data is crucial
• Algorithms as viable products
  • Used in different hardwares => Software Engineering
  • Used in different operating environments => Test Engineering
  • Used with different sensor models => Algorithm Development
Challenges in Site Deployment and Active Usage Scenario

• Primary Objective: Increase operator efficiency
  • How to measure efficiency?

• User Experience
  • "Human machine interface" design
  • Algorithm response time and response confidence

• «Ease of Use» is a critical factor
  • Operator technical skills not matched with the «Algorithm Developer»
  • Simple controls for parameters
  • Algorithm outputs should be visually and perceptually easily recognizable
Challenges in Site Deployment and Active Usage Scenario

• Primary Objective: Increase Operator efficiency
  • How to measure efficiency? => Domain Experience
  • A sample case (compare manual and automatic processing)
    • Scenario 1: Time to find a target in a video clip
    • Scenario 2: Automatic target detection using algorithm
    • $F_c =$ Video Frame Count
    • $T_c =$ Detected Target Count by Algorithm
    • $(F_c \times \text{Algorithm Execution Time}) + (T_c \times \text{Time to eliminate false alarms manually}) < (F_c \times \text{Operator time to process each frame})$

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• User Experience => Custom made interfaces for algorithms
  • «Human machine interface» design
  • Algorithm response time and response confidence

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Challenges in Site Deployment and Active Usage Scenario

- **Primary Objective**: Increase Operator efficiency
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- **User Experience** ➞ Custom made interfaces for algorithms
  - «Human machine interface» design
  - Algorithm response time and response confidence

- «Ease of Use» is a critical factor ➞ **Hyper parameter Optimization**
  - Operator technical skills not matched with the «Algorithm Developer»
  - Simple controls for parameters
  - Algorithm outputs should be visually and perceptually easily recognizable
Vision and Roadmap
Vision and Roadmap

Application of Deep Learning Methods
- Developing algorithms with these perspective
- New algorithms for new problems

Integrated and unified execution of algorithms
- General purpose AI
- A unified input-output system for algorithms
- Ease of integration

Big data analysis
- Geographical data analysis
- Textual data analysis

Swarm Systems
- Autonomous UAV systems
- Sensor Networks
Vision and Roadmap

• Academy-Industry Cooperation

• R&D Projects
  • Swarm UAV

• Product and Architectural Innovation
  • Considering the vision in all projects
  • Productization
  • Constituting teams with experienced and talented members
Thanks…