Computer Vision – Cloud, Smart or Both

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COGS seminars Summer 2012

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Arts C133
Management and Protection
- OTN fault isolation
- Protection switching
- Easy-to-use network management software

High Capacity
- Up to 80 channels
- Up to 10 Gb/s
- 40 Gb/s migration
- Muxpondering/Aggregation

Transparent
- Ethernet, GbE, 10 GbE
- SONET/SDH
- Legacy - PDH
- ESCON, FICON, Fibre Channel
- Video
A Important Element of Security System -
Global Positioning System

- 24 spacecraft in 12 hour circular orbits, with 3 on-orbit spares. Six circular orbital planes, $R=26,560\text{km}$
- All users with clear view of sky see the minimum of 4, but usually see 6-8
Urban Surveillance

Alerts & Meta Data
IP address, Time stamp, GPS location, Alarm type

Smart IP Cameras mapped into 3D space

Data & Meta-Data Storage

Control Room

Responders
Smart Camera’s

IP-camera-based single-chip system S6105 company Stretch c processor Xtensa LX, a network adapter 10/100 Mbs, CMOS-Sensor 2 MP, H264

Texas Instruments DaVinci DSP frequency from 594 to 729 MHz. Network adapter 10/100/1000 Mbs, CMOS-sensor 2 MP, H264

Essential meta data:
IP address, Time stamp, GPS location, Alarm type
Datacentres – Bandwidth Management for the Cloud
Intel's 50Gbps silicon laser transmitter, at bottom left, and optical receiver, at top right

Intel has debuted the prototype of a high-speed fibre optic data system based on silicon chips with integrated lasers and detectors, it will revolutionise affordable data communications across IT.
Terabit data rates

The Path to Tera-scale Data Rates

Today: 12.5 Gbps x 4 = 50Gbps

Scale UP

25 Gbps x 4 = 100Gbps

40G, 100G...

Scale up AND out

12.5 Gbps x 8 = 100Gbps

Scale OUT

Future Terabit+ Links

Could enable cost-effective high speed I/O for data-intensive applications
Global Data Integration Technology
Use of the Global Fibre Network
What resolution is needed
IKONOS Stereo Satellite Imagery
Multispectral Blue, Green, Red, and NIR.
With Ground Control Points (GCP's) - <0.25m GCP accuracy standards for X, Y, Z
Quickbird, 450 km LEO, 98°, sun-synchronous inclination, 60 cm resolution

Multispectral:
Blue: 450 - 520 nanometers
Green: 520 - 600 nanometers
Red: 630 - 690 nanometers
Near-IR: 760 - 900 nanometers
Space Based Infrared Systems (SBIRS)  
12 year design life

**Link Band Function**
1-S down Ka  
Survivable mission data  
1-T down Ka Normal mission data  
2 up QHF Anti-jam commanding  
3 down Ka Wideband sensor data  
4 down S Theater mission downlink  
5 down S Backup SGLS telemetry downlink  
6 up S Backup SGLS commanding

**Diagram Details**
- S-Band Earth Antenna (Links 4)
- Deployable Light Shade
- 22 Cell NiH2 Battery
- 2-Panel Tri-Junction GaAs Solar Arrays 2.8kW
- Dual Band Gimbaled Spot Beams (Links 1, 2, 3)
- Omni Antenna (Links 5, 6)
- 3-Color IPR Payload; Short Schmidt Telescopes with Dual Optical Pointing (Scanner and Starer)
Satellite Image of Military Vehicles
Global Hawk High-Altitude, Long-Endurance, Unmanned Reconnaissance Aircraft, USA

WGS payload can provide more than 4.8 GHz of usable communications bandwidth.

Performance:
- Maximum Endurance: 42 hours
- Loiter Velocity = 343kt
- Maximum Altitude: 65,000ft

Communications:
- Satellite Comms Datalink: 1.5Mbps, 8.67Mbps, 20Mbps, 30Mbps, 40Mbps, 47.9Mbps
- Line of Sight (LOS) Datalink: 137Mbps

Synthetic Aperture Radar (SAR) - 1m/0.3m resolution (WAS / Spot)
Moving Target Indicator - 4kt minimum detectable velocity
Electro-Optical - NIIRS 5.5 / 6.5 (WAS/Spot)
Infrared - NIIRS 5.0 / 6.0 (WAS/Spot)
Visible & Infrared
Wideband Global Satcom (WGS) - Ka Band video transmit and receive – 4.8GHz Bandwidth

- The WGS design includes 19 independent coverage areas – 10 Ka-band and 8 X-band spot beams can be positioned anywhere in the field of view of each satellite.

- Full-Earth coverage in X-band is also provided. Use of phased array technology allows the eight X-band beams to be steered and shaped to apply gain and power exactly where it’s needed.
On board router - 1,900 independently routable sub-channels

Any uplink coverage area to any downlink coverage area
Internet Routing in Space (IRIS) Payload Architecture
Satellite Networks

- Dynamic Capacity
- Agile beams
- MAC
- Fading

- Dynamic routing: deterministic & stochastic
- Heterogeneous network: Satcom, fiber, wireless
- Differentiated services: policy-based, time-deadline

+ Robustness

- Satellite resources extremely precious
EADS Astrium Ka-SAT, 6.1 Tonnes at launch, 15 year lifetime, 11 kW

Eutelsat’s Ka-SAT has a total capacity of more than 70 Gbps, 35 times the throughput of traditional Ku-band satellites.

ViaSat-1 US 100 Gbps

KA-SAT will provide ubiquitous complete coverage of Europe and the Mediterranean Basin through its 82 spot beams in Ka-band
Data Communication Evolution
Impacts Computing Strategy

- Bandwidth management and availability is going to improve greatly
- The Cloud will become increasingly important for security and computer vision
- Integration of Satellite, Fibre, Wireless
- Impacts where you do the Computer Vision
Video Rate Object Detection and Tracking

• How can we locate that object within an image
• We assume 6 degrees of freedom
  - Position x & y
  - Scale (z)
  - In-plane rotation
  - Out of plane rotation (roll and pitch)
  - 2 degree increments in three rotation axes is 540 images
  - At 3 different scales 1620 images
Pragmatic Data Reduction Strategy

- Select an image object and use it to make the filter
- The reference image is rotated -6 to +6 degrees and 7 reference images are created (2 deg increments)
- The reference images are scaled for three different scales and triple filter function bank computed.
- This is just 21 images
Clutter & Noise

- In addition lots of image clutter

- If we assume the images are in thermal IR

- Clutter involves thermal sources (hot objects), foliage, buildings, additional vehicles
OT-MACH Filter

Frequency domain Optimal Trade-off Maximum Average Correlation Height (OT-MACH) filter function

• OT-MACH tunable nature gives:
  - ability to produce easily detected correlation peaks
  - tolerance to untrained target object distortions
  - ability to suppress noise/clutter
Fourier plane transfer function - OT-MACH

- Frequency domain Optimal Trade-off Maximum Average Correlation Height (OT-MACH) filter function:

\[ h = \frac{m^*}{\alpha C + \beta D_x + \gamma S_x} \]

- \( \alpha, \beta \) and \( \gamma \) are the OT-MACH (non-negative) parameters, need to be tuned
- \( m^* \) conjugate mean training set spectrum
- \( C \) is the background clutter power spectral density
- \( D_x \) is the mean power spectral density of the training images
- \( S_x \) is the similarity spectrum of the training images
- Typical values of \( \alpha, \beta \) and \( \gamma \) are: 0.9; 0.8; 0.1
Pre-filter Band Pass

- Morlet wavelet pre-filtering ensures best features are kept
- Low frequencies are removed: copes with lighting variation & bright structures
Tracking

- User selects object
- Algorithms tracks it
  - Must cope with
    - Scale
    - Rotation
    - Occlusions
    - Lighting
    - Clutter
    - Noise
The OT-MACH Tracker - Features

• Performs in real-time on both colour (visible) and infra-red band scenarios.
• Conveniently trainable for real-time target tracking applications.
• Dynamic filter updatability making the algorithm robust for tracking.
Filter Initialisation

- User interface developed for selecting a target in run-time
- Three types of user selection designed and tested
  - Rectangular
  - Circular
  - Assisted active contour
- Rectangular and Circular target selection found to be less accurate compared to active contour based selection
- The filter function is developed for three different scales of the target after scaling the selected target.
Target selection methods

- Rectangular
- Circular
- Active Contour
Active Contour Target Reference

- Active contour selected target used to create a blank background reference image
- The reference image is rotated -6 to +6 degrees and 7 reference images are created (2 deg increments)
- The reference images are scaled for three different scales and triple filter function bank computed.
- A rotationally multiplexed OT-MACH filter is then created using the reference image sets.
Real-time implementation of the OT-MACH tracker

- After Morlet filtering, rotated reference target images are multiplexed together.
- This is Fourier Transformed to create frequency domain filter function
- The Morlet filtered, Fourier transformed input frames, are multiplied by the frequency domain filter function based on the correlation frames frequency \((m)\), selected by the user
- The filter function is applied to every \(m^{\text{th}}\) Morlet filtered input frame to generate a correlation plane output
- We used \(m=5\) for visible and \(m=2\) for IR
Real-time implementation of the OT-MACH tracker

- The filter is automatically updated selecting the current target every update interval set by the end-user (we did this every 25 frames for visible, every 5 frames for IR)

- Rotational multiplexing and triple filter bank increases tolerance of the filter to changes in target orientation and scale changes

- The maximum correlation height values are used to estimate if a filter update is possible or not in the next update interval

- A threshold of 85% of the maximum height value is used to locate the target
Example result and correlation plot

Cross-hair on object

Correlation plot
Kalman filter limitations

• Unlike the OT-MACH tracker, the Kalman filter method is not a suitable estimator for noisy frames, varying velocity targets and extreme scale changes.

• A colour based particle filter method was also investigated and compared with the OT-MACH tracker.
Kalman filter to distinguish between target and non-targets

Kalman filter (red) and OT-MACH tracker (yellow) result
Colour based Particle filter to distinguish between target and non-targets

Particle filter (blue particles and red tracking) and OT-MACH tracker (yellow) result
OT-MACH tracker results
Several video sequences have been used to test the Tracker and the results are found to be accurate, hence, proving the efficiency of the tracker.
OT-MACH tracker results
IR Video Result
OT-MACH tracker results

Colour video example 2
Blurred Video of Truck OT - MACH

Gaussian blurring 7x7 kernel, sigma = 2.0
OT-MACH tracker results
Colour video example 3
Salt and pepper noise (45% noise) results
Salt and pepper noise (45% noise) results
Gaussian Noise SD=55 pixels, zero mean
Gaussian Noise SD=45, zero mean
Conclusions: Tracking

• Optimized robust real-time target tracker.

• The filter is dynamically updatable in run-time.

• The improved active contour based filter initialization and update allows us to maintain a strong and accurate correlation peak at the target location.

• Outperforms the Kalman and particle filter.

• Fast enough for smart camera’s or to be server based.
References

1) P Birch, R Young, C Chatwin, M Farsari, D Budgett, J Richardson, “Fully complex optical modulation with an analogue ferroelectric liquid crystal spatial light modulator,” Optics communications 175 (4), 347-352, 2000
2) PM Birch, R Young, D Budgett, C Chatwin, “Two-pixel computer-generated hologram with a zero-twist nematic liquid-crystal spatial light modulator,” Optics letters 25 (14), 1013-1015, 2000
6) RKK Wang, L Shang, CR Chatwin, “Modified fringe-adjusted joint transform correlation to accommodate noise in the input scene,” Applied optics 35 (2), 286-296, 1996
7) P Birch, R Young, C Chatwin, M Farsari, D Budgett, J Richardson, “Fully complex optical modulation with an analogue ferroelectric liquid crystal spatial light modulator,” Optics communications 175 (4), 347-352, 2000
8) RCD Young, CR Chatwin, BF Scott, “High-speed hybrid optical/digital correlator system,” optical engineering 32 (10), 2608- 2615, 1993
9) PM Birch, R Young, D Budgett, C Chatwin, “Two-pixel computer-generated hologram with a zero-twist nematic liquid-crystal spatial light modulator,” Optics letters 25 (14), 1013-1015, 2000
References

14) RKK Wang, L Shang, CR Chatwin, “Modified fringe-adjusted joint transform correlation to accommodate noise in the input scene,” Applied optics 35 (2), 286-296, 1996
15) P Birch, R Young, C Chatwin, M Farsari, D Budgett, J Richardson, “Fully complex optical modulation with an analogue ferroelectric liquid crystal spatial light modulator,” Optics communications 175 (4), 347-352, 2000
16) RCD Young, CR Chatwin, BF Scott, “High-speed hybrid optical/digital correlator system,” optical engineering 32 (10), 2608- 2615, 1993
28) RK Wang, CR Chatwin, RCD Young, Assessment of a Wiener filter synthetic discriminant function for optical correlation, Optics and lasers in engineering 22 (1), 33-51, 1995
37) L Shang, RK Wang, CR Chatwin, “Frequency multiplexed DOG filter,” Optics and lasers in engineering. 27 (2), 161-177, 1997
38) RK Wang, IA Watson, C Chatwin, “Random phase encoding for optical security,” Optical Engineering 35 (9), 2464-2469, 1996
42) P. Bone, R. C. D. Young, C. R. Chatwin, Position, rotation, scale and orientation invariant multiple object recognition from cluttered scenes, Optical Engineering, Volume 45, pp. 077203-1 to 8, No. 7, 2006