Image Registration: 
A Key Element for Information Processing

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The 21st Century Battlespace
Multichannel Data: Challenge

- **Challenges:**
  - How to define when Multichannel data is an advantage? Circumstances Under Which Additional Multispectral Bands are NOT Needed?
  - How to Merge Multiple Channels into a Useful Composite?
    - Goal for Creation of Geospatial Data
    - Want Automatic Registration of the Images
  - How to Compress Geospatial Data—Terrain Maps
  - Need to Account for:
    - Geometrical Perspectives 3-D Mapping
    - Spatial Resolution of the Sensors
    - Imaging and Non-Imaging Data Sources (ELINT)
    - Data Representation
Registration

Registration Means Establishing a Mathematical Relationship or Address List Between Pixels in One Image and Their Counterparts in Another Image With Unknown Spatial Offsets. In Computer Vision this is the Correspondence Problem

• Goal: *Automated* Registration
  • Tie Points are Objects or Features derived from the Image
  • Registration Depends on Defining Objects and Their Counterparts in A Different Image Then Matching the “Correct” Pair Sets
• Pair Matching to Model Based Upon Dominant Motion
  – Affine (Rotation, Shear, Translation, Scale)
  – Projective
Types of Acquired Data

Registration is the Key

- Overhead Imagery
- Low Altitude Photo
- Infrared Video
- LADAR Intensity
- LADAR Range
- Meta Data
- Elevation Data
- Registration is the Key
Requirements of a Registration Algorithm

- Need for Contrast Invariant Methods
- IR Signature Changes: Due to Gain Controls, Changes in Lighting, Atmospheric Conditions, and Background
- Completeness: the Whole Image Must Be Described
- Classical Algorithms Such As Correlation Techniques: Don’t Meet Requirements Very Sensitive to Illumination Changes
- Reasonable execution time
Registration (circa 2001)

6.1 and 6.2 D&I ONR Code 311 Image Processing Technology
- Dynamic Image Correspondence is Not Yet Solved for Full 3D Motion
Registration (circa 2003)

6.1 and 6.2 D&I ONR Code 311 Image Processing Technology
- Goal: Dynamic Registration for Full 3D Motion
Benefits of Registration

Registration Enables:

– Change Detection (Demonstration)
– Interframe Fusion
  • Viewpoint Stabilization for Video Sequences
    – Fix the Background (Demonstration)
    – Keep an Object Fixed
– Mosaic (Demonstration)
– Multi Channel Fusion
– Geo-Location (Demonstration)
– Navigation
Automated Mosaic

From Constrained Looks . . .

To a Registered Global View Automatically

CIAR Based Mosaicking
Fully Automated:
No Human Selected Tie Points
Full Affine Transformation
Partial Perspective Transform

For Official Use Only (FOUO)
Change Detection / Passive MTI

150 Frame Mosaic of IR Sequence

Mid-wave Infrared Video Imagery

Moving Vehicles in Stabilized Frames

Amber Galileo (Raytheon Radiance HS) Sensor on Helicopter Platform ~ 1000 ft AGL
Stereo Imaging

- Stereo Ranging or Depth from Video
- Disparity is the relative change when viewing from two different positions
  \[
  \text{Disparity} = x_{\text{left}} - x_{\text{right}}
  \]

Vehicle Movement

\[
\text{Height} = \frac{\text{(Baseline)} \times \text{(Focal Length)}}{\text{(Disparity)}}
\]

- Fundamental Difficulty of the Stereo Correspondence Problem: Finding Corresponding Points Between Left & Right Image
Example

- Two frames from above Library Tower
Example

- 3-D reconstruction
Image Stabilization via Automatic Registration

Original Video

Courtesy Cognitech, Inc.

Stabilized, Enhanced
Multi-Channel Image Registration Using Level Set Features

Color Image (Spring 1997) → Extracted Regions of Interest

Mid-Wave IR Image (Sep. 1997) → Color to Grayscale

Registered Visible & IR Images

- Automated Registration
- No pre-designated control points
- Additional refinement needed
  - Offsets evident
  - Affine transformations not planar projective
Image - Map Registration

Same technique as in previous viewgraph has been applied to register images to DEM.

IR Video ~ 2 m/pixel Resolution (416.2 m²); Color Aerial Photo ~ 5 m/pixel Res. (1.2 km²);
Video Sequence *(Collected Sep. 1999)* Automatically Registered to 1200 x 1100 pixel Sub-Region of USGS GeoTIFF Reference Image *(Collected 1994, 1m Resolution, 6420 x 7620 pixels)*
- Projected Video Frame Correspondence Over Reference Mapped in Red
- IPEX Adapting for use with Digital Point Positioning Data Base (DPPDB) Enhanced Precision
- Development Progressing from Less to More Oblique Viewing Angles - No Metadata Used for Search
Reference Coordinates Automatically Mapped to Video

- User Designates Point In Tactical Video (Corresponding Frame Coverage Mapped in Red )
- Associated Target Coordinate Automatically Extracted from Reference Imagery and Pushed to Video
  + Indicates Target Position on Reference
Ground Truth

• The Longer South Tank seen in 1994 USGS GeoTiff Reference Image but not in 1999 Flight Video Sequence was indeed Removed.

• The Automatically Georegistered Coordinates at Left End of the Tank in the Video Frames Agree within 0.01 to 0.02 Arc Seconds of Those Recorded with the Ground Based Handheld Garmin GPS Receiver (Within Error of Handheld Unit).

N35:41:27.9    W117:40:57.5 (Garmin GPS III Plus Receiver)
N35:41:27.88   W117:40:57.49 (Registered Coordinates From Video)
Open Problems

• Overcoming 3D Projective Geometry
  – Exploit Multiple View Tactical Imagery
  – Large Motion/Camera Calibration Parameters
    • Rapid Zooms, Large Rotations, Oblique Views
  – Overcome Multiple View Occlusions
    • Detect Presence of Occlusions
  – Exploit Motion Parallax
  – Autonomous Navigation in Highly Variable and Complex Terrain (Urban Canyons)
Open Problems cont’d

• Multimodal Registration
  – Avoidance of Geometrically Non-invariant Approaches
  – Registration of 2-d data to 3-d Surfaces
    • Digital Elevation Maps, LADAR
    • Digital Point Position Database, Stereopsis
  – Application to Multiple Strike Warfare
Conclusion

• Correspondence problem still not fully solved
• Exploitation relies heavily on ‘registered’ data/imagery
• 3-d invariance for imagery?
Additional Material
Problem Statement

Specifically:
Given a sequence of range surfaces collected in level flight, automatically register the sequence.
Nadir View
Examples

Creation of local DEM on the fly.
Example

25 frames, relatively featureless.
Contrast Invariant Registration (CIR)

- Convex Contrast enhances brighter parts of the image
- Identity linear Contrast
- Concave Contrast enhances darker parts of the image

Image | Shape Boundaries | Contrast Intensity
---|---|---
Altered Contrast
Original Image
Altered Contrast
Moving Target Detection

Original  Stabilized  Stabilized Difference
Motion Detection Example
Landing Aircraft in Clutter

Original Mid-Wave IR Image Sequence

Stabilized View

Motion from Stabilized View
Automatic Mosaic Reconstruction from Decimated Infrared Video

Decimated IR Video

- Denoised using Spatio-Temporal Total Variation Filters
- CIAR Global Velocity Estimates used to Automatically Construct Registered Mosaic
- **NOTE**: Vertical Striation from Optical Non-uniformity -- see lower left corner in original sequence.

(Click Image to Animate)