Person Tracking and Gesture Recognition in Challenging Visibility Conditions Using 3D Thermal Sensing

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Problem: Visually Tracking a Person

Challenging visibility:

• Variable lighting
  – Pitch black
  – Nighttime

• Sunlight

• Rain

• Smoke

• Occlusions

• Other people
Proposed Solution: 3D Thermal Sensing
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Person’s head
Presented Solution: PROWL

The sensor system: Perception for Robotic Operation over Widespread Lighting (PROWL)

- PROWL uses
  - thermal stereo image processing
  - on-board processing

- PROWL performs
  - person tracking
  - gesture recognition.
Presented Solution: PROWL

Can track a human target and recognize gestures well in tested environments:

- Air-conditioned, 72° F, well-lit indoors
- Air-conditioned 72° F, pitch-black indoors
- Warm, 85° F, smoke-filled, well-lit indoors
- Hot, 96° F, sunny outdoors
- Warm, 80° F, nighttime outdoors
Method: Tracking using 3D Thermal Sensing

- Create 3D point cloud from stereo camera pair.
- Track using simple algorithms in point cloud.
PROWL Demo: Additional Hardware

• Mounted PROWL on a mobile robot base (TRACBot)
  – With pan-tilt mount
• Moved robot based on detected gestures

More videos at:

https://personal.traclabs.com/~pbeeson/PROWL/
Demonstration of PROWL system mounted on mobile robot in various visibility conditions
PROWL: Perception for Robotic Operation over Widespread Lighting

- Sensor system
  - 2 thermal cameras
  - 2 RGB cameras
  - Computational core

- Specified and conceived by TRACLabs Inc. under an Army SBIR contract
- Hardware assembled by Carnegie Robotics LLC
PROWL Hardware Specifics

- RGB Cameras
- Computational Core
- Thermal Cameras
Tracking

- Tracks a target in the cloud using ICP
- Fits a sphere of points to the point cloud near the previous known location
- Moves sphere up to find the head
- Ignores points outside the human temperature range
Gesture Recognition

- Fits a cylinder of points to the point cloud relative to the tracked head location
- Looks for left arm raised, right arm raised, or both arms raised.
- Ignores points outside the human temperature range
Evaluation: Environments

Tested in various environments:

• Air-conditioned, 72° F, well-lit indoors
• Air-conditioned 72° F, pitch-black indoors
• Warm, 85° F, smoke-filled, well-lit indoors
• Hot, 96° F, sunny outdoors
• Warm, 80° F, nighttime outdoors
Evaluation: Comparison

- PROWL creates both RGB and thermal point clouds
- Attempting tracking with same algorithm in both
<table>
<thead>
<tr>
<th>Environment</th>
<th>Action</th>
<th>% frame correctly tracked</th>
<th>Using RGB Point Cloud</th>
<th>Using Thermal Point Cloud</th>
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<tbody>
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<td>Indoors, well-lit, cool</td>
<td>Walking</td>
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<tr>
<td></td>
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<td>Walking</td>
<td>11.4</td>
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</tbody>
</table>
Notable Points

• Environment can be almost entirely filtered out in air-conditioned indoors
Notable Points

- Darkness and smoke have little impact on thermal vision
Notable Points

• Darkness and smoke have little impact on thermal sensing
Conclusion and Questions

• 3D thermal sensing can be used to track humans
  – Particularly suited for certain environments
    • E.g., cool + indoors

• PROWL demonstrates the feasibility with high success in tested environments

• More videos: [https://personal.traclabs.com/~pbeeson/PROWL/](https://personal.traclabs.com/~pbeeson/PROWL/)
PROWL: Perception for Robotic Operation over Widespread Lighting

- Sensor system
- Generates thermal and RGB point clouds using stereo vision
PROWL: Perception for Robotic Operation over Widespread Lighting

- Sensor system
- Generates thermal and RGB point clouds using stereo vision
- Onboard computational core
  - Runs tracking
  - Runs gesture recognition
Other Methods

• Advanced detection and tracking algorithms
• Sensor fusion
  – RGB + thermal + depth
• Tactile thermal sensing