Automated In-Home Assistive Monitoring with Privacy-Enhanced Video

Alex Edgcomb
Frank Vahid
University of California, Riverside
Dept. of Computer Science & Engineering

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Assistive monitoring goals

- Fall detection
- Leave at night but not return
- In region too long
- Arisen in morning
- Unusually inactive
- Energy trends

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Reasons for video in assistive monitoring

Body-worn
Pro: Anywhere
Con: Not always worn

Detect many events

Privacy enhance-able
Reasons for privacy enhancements

• Participants age 65+ felt cameras were intrusive, while "many felt that [silhouetting] was more appropriate."\(^1\)

Privacy enhancements considered

Raw  Blur  Silhouette  Oval  Box
Person tracking and MBR extraction
via foreground-background segmentation

- Video frame
- Background image
- Foreground
- Minimum bounding rectangle (MBR)
Recording environment
Energy expenditure estimation 1 of 2

Fidelity = correlation(Video, BodyBugg)

0.997 0.994 0.998 0.997 1.000

- Fidelity of privacy-enhanced video was the same as raw video (p < 0.001)

Energy expenditure estimation 2 of 2

Accuracy

90.9%  80.5%  85.0%  85.6%  84.3%

• Accuracy of privacy-enhanced video was less than raw video (p < 0.001)

Fall detection 1 of 2
## Fall detection 2 of 2

<table>
<thead>
<tr>
<th>Sensitivity(^4)</th>
<th>0.91</th>
<th>1.00</th>
<th>0.91</th>
<th>0.91</th>
<th>0.82</th>
</tr>
</thead>
<tbody>
<tr>
<td>Specificity(^4)</td>
<td>0.92</td>
<td>0.67</td>
<td>0.75</td>
<td>0.92</td>
<td>0.92</td>
</tr>
</tbody>
</table>

In-room-too-long, and leave-at-night-but-not-return

Sensitivity/Specificity

1.0/1.0  1.0/1.0  1.0/1.0  1.0/1.0  1.0/1.0

• Raw and privacy-enhanced video had perfect sensitivity and specificity

Exit from left
Enter to left

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Arisen person enters main living area in morning

Sensitivity/Specificity

1.0/1.0  1.0/1.0  1.0/1.0  1.0/1.0  1.0/1.0

- Raw and privacy-enhanced video had perfect sensitivity and specificity
In region too long

Sensitivity/Specificity
1.0/1.0  0.5/1.0  1.0/1.0  1.0/1.0  1.0/1.0

- Raw and privacy-enhanced video had perfect sensitivity and specificity, except blur’s sensitivity.

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Abnormally inactive during day

Sensitivity/Specificity
1.0/1.0  1.0/1.0  1.0/1.0  1.0/1.0  1.0/1.0

• Raw and privacy-enhanced video had perfect sensitivity and specificity

Person home but inactive for extended period
Most goals were achieved equally well even with privacy enhancements

<table>
<thead>
<tr>
<th></th>
<th>Energy estimation fidelity / accuracy</th>
<th>Fall detection sensitivity / specificity</th>
<th>In room too long sensitivity / specificity</th>
<th>Arisen in morning sensitivity / specificity</th>
<th>In region too long sensitivity / specificity</th>
<th>Abnormally inactive during day sensitivity / specificity</th>
</tr>
</thead>
<tbody>
<tr>
<td>Raw</td>
<td>0.997 / 90.9%</td>
<td>0.91 / 0.92</td>
<td>1.0 / 1.0</td>
<td>1.0 / 1.0</td>
<td>1.0 / 1.0</td>
<td>1.0 / 1.0</td>
</tr>
<tr>
<td>Blur</td>
<td>0.994 / 80.5%</td>
<td>1.00 / 0.67</td>
<td>1.0 / 1.0</td>
<td>1.0 / 1.0</td>
<td>0.5 / 1.0</td>
<td>1.0 / 1.0</td>
</tr>
<tr>
<td>Silhouette</td>
<td>0.998 / 85.0%</td>
<td>0.91 / 0.75</td>
<td>1.0 / 1.0</td>
<td>1.0 / 1.0</td>
<td>1.0 / 1.0</td>
<td>1.0 / 1.0</td>
</tr>
<tr>
<td>Oval</td>
<td>0.997 / 85.6%</td>
<td>0.91 / 0.92</td>
<td>1.0 / 1.0</td>
<td>1.0 / 1.0</td>
<td>1.0 / 1.0</td>
<td>1.0 / 1.0</td>
</tr>
<tr>
<td>Box</td>
<td>1.000 / 84.3%</td>
<td>0.82 / 0.92</td>
<td>1.0 / 1.0</td>
<td>1.0 / 1.0</td>
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Limitations of cameras and this work

- Not feasible locations
- Not outside home

- Actors all males in 20s
Future work

• Increase variability in experimentation
• Cameras and sensors working together
• Algorithms that adapt to the privacy enhancement

Conclusion

• Privacy-enhanced video is viable for 8 common monitoring goals

• , , , and had little loss in goal achievement

• Blur had loss in goal achievement

• Video data sets linked on my homepage:
  – http://www.cs.ucr.edu/~aedgcomb/