Automated Monitoring of Hardhats Wearing for Onsite Safety Enhancement

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Motivation
Motivation

- The Bureau of Labor Statistics in U.S.: “hardhats were worn by only 16% of those workers who sustained head injuries, although two-fifths were required to wear them for certain tasks at specific locations.” [1]

- Reasons [2]
  - Discomfort while wearing hardhats
  - Disassociation with the safety issues
  - … …

- Need to monitor the wearing of hardhats onsite
Current Practice

Indicate either:  \( S = \) Satisfactory/Yes  \( U = \) Unsatisfactory/No

NOTE: A check in the box to the right of the heading indicates the entire workplace is in compliance.

<table>
<thead>
<tr>
<th>PERSONAL PROTECTIVE EQUIPMENT</th>
<th>H</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>Safety glasses and/or goggles available &amp; being used? [1926.102]</td>
<td></td>
<td>MSDS openly available to all employees</td>
</tr>
<tr>
<td>Face shield available for bulk liquid tasks? Grinding? [1926.102]</td>
<td></td>
<td>Flammable liquids are in approved storage in accordance with OSHA Flammable liquids storage control [1910.1200(f)(5)]</td>
</tr>
<tr>
<td>Hand protection used/worn as required? [1926.951]</td>
<td></td>
<td>All hazardous containers labeled</td>
</tr>
<tr>
<td>Foot protection worn as required? [1926.96]</td>
<td></td>
<td>Supplies on hand for accidental spill</td>
</tr>
<tr>
<td>Hearing protection worn where required? [1926.101]</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hard hats worn on construction site at BNL? [1926.100]</td>
<td></td>
<td>LADDERS</td>
</tr>
<tr>
<td>Respirators if required? Type? [1926.104]</td>
<td></td>
<td>Ladders are safe and inspected periodically</td>
</tr>
<tr>
<td>Fall protection, full body harness &amp; lanyard used at &gt; 6 ft? [1926.104]</td>
<td></td>
<td>Stair rails - for 30” change in elevation</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>ELECTRICAL SAFETY</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
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</tr>
</tbody>
</table>

|  | |

| Extension & straight ladders on job site |

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ICSC15  
Canadian Society for Civil Engineering

Concordia University
Related Research Work

- Sensor based alerts for PPE wearing
  - E.g. RFID-based tags and portal \[3\]

- Limitation
  - Checking at the portal only
Related Research Work

- Vision based alerts for PPE wearing
  - No need to attach tags
- RGB-D cameras \[^4\]
  - Indoor, small-scale space (5m x 5m x 3m)
- Video cameras \[^5\]
  - Failure to detect white hardhats

Incorrectly issuing the alert \[^5\]
Objective

- To create an automatic method to detect whether the persons are wearing hardhats on construction sites
  - Open, large-scale construction sites
  - Hardhats with different colors
Proposed Methodology

Site videos → Hardhat detection → Hardhats → Pair-wise matching → Human bodies → Human body detection → Safety alerts
Human Body/Hardhat Detection

Detection using histogram of oriented gradients (HOG) features
Pair-Wise Matching

Region (1)

Region (2)
Implementation and Results

- Implementation
  - Microsoft Visual C# .NET Framework 4.0 environment

- Test: 3320 video frames

- Evaluation criteria
  - True positive (TP), false positive (FP), and false negative (FN)

\[
\text{Precision} = \frac{TP}{(TP+FP)} \quad \text{(Eq.1)}
\]
\[
\text{Recall} = \frac{TP}{(TP+FN)} \quad \text{(Eq.2)}
\]
TP, FP and FN Definitions

- Human body detection
- Hardhat detection
- Safety alerts

<table>
<thead>
<tr>
<th>Category of safety alert</th>
<th>Safety alert is issued by the method</th>
<th>Safety alert should be issued in reality</th>
</tr>
</thead>
<tbody>
<tr>
<td>TP</td>
<td>Yes</td>
<td>Yes</td>
</tr>
<tr>
<td>FP</td>
<td>Yes</td>
<td>No</td>
</tr>
<tr>
<td>FN</td>
<td>No</td>
<td>Yes</td>
</tr>
</tbody>
</table>
# Results

## Human body detection vs. Hardhat detection

<table>
<thead>
<tr>
<th>Metric</th>
<th>Human body detection</th>
<th>Hardhat detection</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Situation 1</td>
<td>Situation 2</td>
</tr>
<tr>
<td>TP</td>
<td>3026</td>
<td>2247</td>
</tr>
<tr>
<td>FP</td>
<td>61</td>
<td>9</td>
</tr>
<tr>
<td>FN</td>
<td>291</td>
<td>838</td>
</tr>
<tr>
<td>Precision (%)</td>
<td>98.0</td>
<td>99.6</td>
</tr>
<tr>
<td>Recall (%)</td>
<td>91.2</td>
<td>72.8</td>
</tr>
</tbody>
</table>

## Safety alert from the proposed method

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<tr>
<th>Metric</th>
<th>Situation 1</th>
<th>Situation 2</th>
</tr>
</thead>
<tbody>
<tr>
<td>Precision (%)</td>
<td>53.6</td>
<td>94.3</td>
</tr>
<tr>
<td>Recall (%)</td>
<td>87.7</td>
<td>89.4</td>
</tr>
</tbody>
</table>
Video Demo
Conclusion and Future Work

- An automatic vision-based method to detect whether onsite people are wearing hardhats
  - High precision and recall for issuing safety alerts
  - Built upon the high recall for hardhat detection
- Limitation
  - Background subtraction $\rightarrow$ moving workers
- Other site safety violations with video cameras
Thank you!

Questions?
References


