An Automated Tool for Detecting and Preventing Unsafe Stair Use

Jasper Snoek[1], Jesse Hoey[2,3], and Alex Mihailids[1,2]

[1]Dept. of Computer Science, University of Toronto, Toronto, ON; [2]Toronto Rehabilitation Institute, Toronto, ON; [3]University of Dundee, Dundee, Scotland;

Background and Motivation

- In Canada more than 40,000 community dwelling older adults fall each year [1] and a significant proportion of these falls occur on the stairs [2]. In the U.S. over one million people received hospital treatment due to stair related injury in 2005 [3].
- A system that is able to detect unsafe events on stairs could be used to a) further our understanding of the causes and catalysts of unsafe events and b) dispatch help in the event of an injury.
- **The purpose of this project is to develop an artificially intelligent tool that can automatically detect unsafe events on stairs using video (Figure 1).**

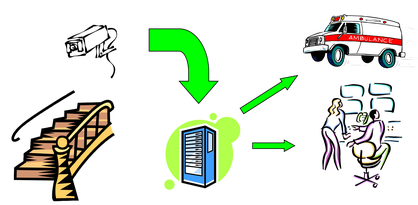

Figure 1: Overview - The system analyses video data of people descending stairs and detects any unsafe events that occur. The results of this analysis could be used to study the causes of stair events or dispatch for help in the event of emergency.

Body Motion Analysis

- Optical flow is used as a high level representation, capturing a person's overall body motion (Figure 2). We used the robust dense optical flow algorithm of Black and Anandan [4] computed over a background subtracted silhouette..

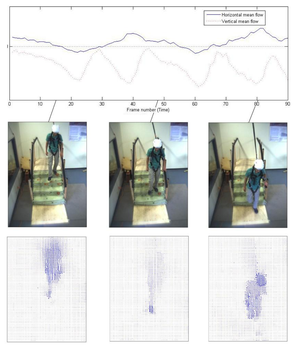

Figure 2: The estimation of a person's body motion during stair descent using optical flow. Using a sequence of images (middle), the system computes the motion of each pixel (bottom) and the average overall progression of motion (top).

Bayesian Foot Tracking

- The motion of the feet is a very strong indicator of a whether or not a person is safely traversing stairs.
- The safe traversal of stairs necessitates a pattern of motion of the feet which restricts idiosyncratic behaviour – this makes the detection of unsafe events easier as errors due to unique quirks in a person's gait (such as swinging one's arms) can be avoided.
- The system tracks both feet simultaneously using a Bayesian Monte Carlo importance sampling algorithm (Figure 4) with mixed state dynamics [5] and a Histograms of Oriented Gradients (HOG) [6] appearance model (Figure 3).

Figure 3: This figure shows the log likelihood that the 21x21 window centered at each pixel contains a foot given our HOG based appearance model. (a) is the original image, in (b) each pixel's value is it's log-likelihood and (c) shows a surface map of the log likelihoods over a small window centered around the right foot.

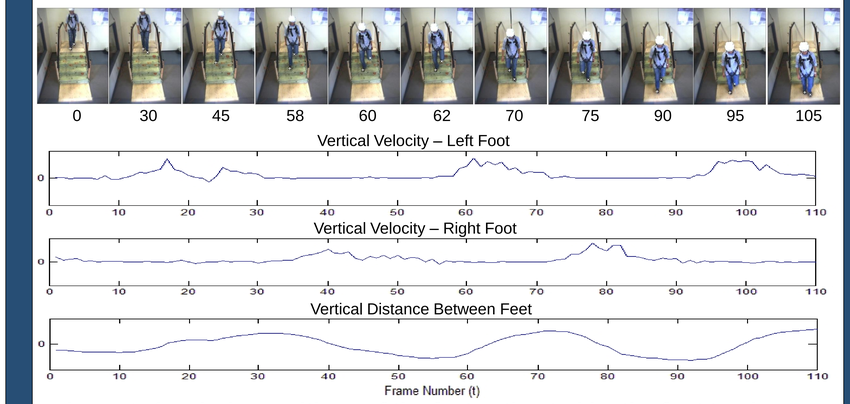

Figure 4: (Top) The positions of the feet estimated by the foot tracker are shown for the right (white 'X') and left (white '+') feet for a stair descent sequence containing an overstep. (Bottom) Statistics derived from the tracked foot locations are used to create a simple representation of the sequential progression of the feet during a stair descent.

Detecting Unsafe Stair Use

- A hidden Markov model (HMM) is used to create a statistical representation of the sequential progression of features derived from the optical flow and foot tracking data for a series of normal stair descents.
- Given the HMM, we compute the likelihood that a newly captured stair traversal is normal. Anomalous (unsafe) events are classified based on a cost function that thresholds the likelihood and controls the trade-off between precision and recall.

Experiments

- Trials were conducted with five unbiased subjects simulating three types of events (20 oversteps, 20 heel-slips, and 20 normal) while descending a staircase.
- Using a leave-one-out cross-validation methodology, the system was trained on all but one subject and test results were reported for the remaining subject.

Results and Future Work

- The system was able to correctly classify 93.49% of stair descents as either as normal or anomalous for people of which it had no prior knowledge.
- For further details, please see [7] and http://www.cs.toronto.edu/~jasper/stairpage.html (for videos).
- The system will be deployed in public spaces where it will automatically gather data and classify events as they occur.
- Further work will explore using computer vision and machine learning to detect falls and anomalous gait throughout the home as part of a fully automated emergency response system.

References & Acknowledgements

[1] Public Health Agency of Canada.(2005). Report on Seniors' falls in Canada, Ottawa, Canada.
[2] Lord, S. R.; Sherrington, C. & Menz, H. B. (2001), *Falls in Older People: Risk Factors and Strategies for Prevention,* Cambridge University Press, Cambridge, England.
[3] Consumer Product Safety Commission. (2005), 'National Injury Surveillance System – Online', Washington D.C.
[4] Black, M. J. & Anandan, P. (1996), 'The robust estimation of multiple motions: parametric and piecewise-smooth flow fields', *Computer Vision & Image Understanding*. **63**(1), 75-104.
[5] M. Isard, A. Blake, A mixed-state CONDENSATION tracker with automatic model-switching. *ICCV*, 1998, pp. 107–112.
[6] N. Dalal, B. Triggs, Histograms of oriented gradients for human detection, *CVPR*, 2005, pp. 886–893.
[7] Jasper Snoek, Jesse Hoey, Liam Stewart, Richard S. Zemel and Alex Mihailidis. An Automated Tool for Detecting Anomalous Events on Stairs. *Journal of Image and Vision Computing*. Vol 27, pp. 153-166. (Jan 2009).

This research was funded in part by the Canadian Institutes of Health Research Institute of Aging Pilot Program.

UNIVERSITY of TORONTO | Toronto Rehab Everything Humanly Possible | UNIVERSITY OF DUNDEE

IATSL Intelligent Assistive Technology and Systems Lab