Computational deglutition

Ervin Sejdic, University of Pittsburgh

***Abstract*— In this talk, we will cover a novel computational field called computational deglutition developed by engineers and speech-language pathologists to address swallowing difficulties (dysphagia), a major health issue associated with aging and many neurodegenerative diseases.**

I. Introduction

Swallowing is a typical daily activity for all of us, and it represents a sensorimotor activity that moves food, liquids, and saliva from the oral cavity to the stomach. As swallowing requires a very high level of coordination between multiple subsystems during one to two seconds, it is often It is considered one of the most complex sensorimotor functions. Given the complexity of the process, dysphagia (swallowing difficulties) can develop due to a variety of neurological conditions (e.g., stroke, cerebral palsy, Parkinson's disease), head and neck cancer and its treatment, or trauma. Many various symptoms are indicative of dysphagia including but not limited to difficulty chewing and swallowing food or liquids, choking or coughing before, during, or after eating. Dysphagia is very prevalent in various patient groups. For example, 50 to 75% of stroke patients and 60% to 70% of patients who undergo radiation therapy for head and neck cancer have dysphagia. Additionally, complications associated with dysphagia are the cause of over 60,000 people annual deaths, and these complications associated with dysphagia drastically increase healthcare costs as well. It is estimated that dysphagia costs exceed one billion dollars per year.

Remarkable improvements in the management of dysphagia have been made over the last 40 years as we have gained an increased understanding of this potentially devastating condition. However, the field is technologically underdeveloped, i.e., many recent advances in technology have not over spilled to the dysphagia community, and there is a dire need, especially to automate some of the analysis and assessment steps. Therefore, as recent advances in computational power and algorithms have made drastic changes in other medical branches, a new data analytics subfield called computational deglutition is established by a group of engineers and clinicians. Computational deglutition is a translational data analytics subfield aimed at aimed at the development of clinically relevant algorithms that will aid clinicians during the assessment and treatment of swallowing disorders.

* This work was sup-ported by the Eunice Kennedy Shriver National Institute of Child Health& Human Development of the National Institutes of Health under AwardR01HD092239 and Award R01HD074819.

E. Sejdic is with the University of Pittsburgh, PA 15213 USA, phone: 412-624-0508; e-mail: esejdic@ieee.org.

II. Methods

Data presented in this talk was acquired from patients undergoing a videofluoroscopy exam at the University of Pittsburgh Medical Center. All patients provided signed informed consents. Video images were recorded at 60 frames per second and the resolution of images is clipped into 720×1080. Cervical auscultation signals were recorded using two different sensors. A tri-axial accelerometer (ADXL 327, Analog Devices, Norwood, Massachusetts) was attached to the anterior of the patient's neck. The signals extracted from the tri-axial accelerometer sensors are recorded with a National Instrument 6210 DAQ at a sampling rate of 20 kHz by the LabVIEW Program Signal Express (National Instrument, Austin, Texas). A microphone (model C 411L, AKG, Vienna, Austria) was also placed below the accelerometer to record swallowing sounds.

III. Results

Our current results indicate that we can assess swallowing function via a combination of artificial intelligence methods and novel sensors such as accelerometers and microphones. In particular, we can infer about swallowing safety and several physiological events, previously only observable via a videofluoroscopy exam. Furthermore, our research demonstrated that we can automatically analyze X-ray images with accuracies comparable of human raters.

IV. Discussion & Conclusion

While we have made significant steps to address the assessment of swallowing difficulties, there are important research questions left to answer. First, more studies are needed to understand how these algorithms behave when food of different consistencies are presented to patients. Second, the automatic analysis of videoflourscopic images is a completely underdeveloped area, and more algorithms that are relevant to clinical exams are much needed.

Acknowledgment

The author would like to thank Dr. James L. Coyle and all graduate students that participated in this research.

References

[1] E. Sejdić, G. A. Malandraki, J. L. Coyle, "Computational deglutition: Signal and image processing methods to understand swallowing and associated disorders," *IEEE Signal Processing Magazine,* vol. 36, no. 1, pp. 138 – 146, Jan. 2019..

[2] J. M. Dudik, J. L. Coyle, E. Sejdić, "Dysphagia screening: Contributions of cervical auscultation signals and modern signal processing techniques," *IEEE Transactions on Human-Machine Systems,* vol. 45, no. 4, pp. 465-477, August 2015.

Detecting Agitation in People Living with Dementia from a Wearable Multimodal Sensor

Shehroz S. Khan, KITE – Toronto Rehabilitation Institute, Canada

***Abstract*— People Living with Dementia (PLwD) often exhibit behavioral and psychological symptoms, such as episodes of agitation and aggression. Agitated behaviour in PLwD causes distress and increases the risk of injury to both the patients and the caregivers. In this paper, we present the use of a multi-modal wearable device that captures motion and physiological indicators to detect agitation in PLwD. We hypothesize that combining multi-modal sensor data will be more effective to identify agitation in PLwD in comparison to a single sensor. This paper presents the results of a unique pilot study to collect motion and physiological data from PLwD admitted to a Specialized Dementia Unit. The classification results on 14 participants from 481 days of data collected from PLwD show strong evidence to support our hypothesis and highlight the importance of using multi-modal sensor data for detecting agitation events in this population.**

I. Introduction

With the aging population, the number of people living with dementia (PLwD) is increasing. The current number of PLwD worldwide is approximately 50 million, with nearly 10 million new cases every year [1]. The majority of PLwD will experience Behavioral and Psychological Symptoms of Dementia (BPSD), representing a heterogeneous group of non-cognitive symptoms. Agitation is one of the most common types of BPSD present in PLwD [2] that encompasses a range of behaviours, such as wandering, repetitive and purposeless behaviour, socially inappropriate activities, and physically and verbally aggressive or non-aggressive behaviours. Agitation events are understood to be in part related to the unmet needs of PLwD and the distress associated with them; these events place themselves and others at risk for harm.

II. Methods

Various clinical measures have been developed to assess agitation, such as Pittsburgh Agitation Scale (PAS) and Cohen-Mansfeld Agitation Inventory (CMAI) [3], [4]. However, these assessment tools are qualitative, prone to subjective and imprecise ratings, and retrospective in nature, thus are not helpful at prediction of agitation events. Additionally, it is very difficult for the staff in a care facility (or a caregiver at home) to continually monitor PLwD. Therefore, it is important to develop objective and automatic methods of detecting agitation in PLwD to provide interventions to avoid harm to the patients and staff. Previous studies report the use of accelerometer (or actigraphy) to detect agitation in PLwD [5]. In this study, for the first time, we expand upon the previous work using motion data (collected through accelerometer) by adding physiological indicators such as blood volume pulse, electrodermal activity, and skin temperature to detect agitation. We hypothesize that multi-modal sensor data will be more effective in detecting agitation behaviour in PLwD in comparison to a single sensor due to the increased amount of data and fusion of different sensors [6] .

III. Results

We collected and labeled wearable multimodal data for more than 600 days from 20 participants. We extracted three groups of features, i.e. general time and frequency features, signal-specific features, and hybrid features that combines the features of previous two types. The nurses on the unit were trained to report start and end timing of agitation events in their charts. Additionally, fifteen cameras were installed in the unit, which were later on used to fine tune the agitation labels. Our results on 14 participants showed the superiority of multimodal sensors (AUC = 0.85) over single sensors in detecting agitation in PLwD using hybrid features. We are now investigating the use of video camera feeds from the study to detect agitation in PLwD in a non-invasive manner.

References

[1] World Health Organization, Dementia: a public health priority, 2012

[2] Cerejeira, J., Lagarto, L. and Mukaetova-Ladinska, E., 2012. Behavioral and psychological symptoms of dementia. Frontiers in neurology, 3, p.73.

[3] J. Rosen, L. Burgio, and M. e. a. Kollar, "The pittsburgh agitation scale: a user-friendly instrument for rating agitation in dementia patients," The American Journal of Geriatric Psychiatry, vol. 2, no. 1, pp. 52–59, 1994.

[4] J. Cohen Mansfield, "Conceptualization of agitation: results based on the cohen-mansfield agitation inventory and the agitation behavior mapping instrument," International Psychogeriatrics, vol. 8, no. S3, pp. 309–315, 1997

[5] Khan, S.S., Ye, B., Taati, B. and Mihailidis, A., 2018. Detecting agitation and aggression in people with dementia using sensors—A systematic review. Alzheimer's & Dementia, 14(6), pp.824-832.

[6] Khan, S.S., Spasojevic, S., Nogas, J., Ye, B., Mihailidis, A., Iaboni, A., Wang, A., Martin, L.S. and Newman, K., 2019, July. Agitation Detection in People Living with Dementia using Multimodal Sensors. In 2019 41st Annual International Conference of the IEEE Engineering in Medicine and Biology Society (EMBC) (pp. 3588-3591). IEEE.

A Passive EEG-Based Brain Computer Interface for Assessment of Visuospatial Neglect

Murat Akcakaya, University of Pittsburgh

***Abstract*— Spatial neglect (SN) is a neurological deficit characterized by inattention to stimuli in the contralesional visual field after stroke. In this paper, we introduce an objective EEG test for SN assessment that overcomes the limitations of the traditional paper and pencil tests. In particular, the proposed test provides information about severity of SN. Moreover, it uses dynamic objects and distractors common in a real-life environment while the traditional tests are static.**

I. Introduction

Spatial neglect (SN) is a common and disabling condition following stroke [1]. Spatial neglect is a perceptual disorder that results in inattention to stimuli on the contralesional side. Individuals with spatial neglect may demonstrate inattention to one side of their body, which results in a failure to shave one side of their face or dress one side of their body. They may also demonstrate neglect of items in a portion of their environment, failing to locate food items on one side of the plate, or failing to notice items in one side of the hallway. This culminates in significant disability and concern for safety. While right-side neglect is possible, individuals with this condition most often neglect the left side. Spatial neglect occurs in 28.60% of the stroke population. It can result from lesions throughout the attentional networks, the right inferior parietal lobe, the ventral frontal lobe, or the superior temporal lobe.

One of the most commonly used neglect assessments is the Behavioral Inattention Test (BIT). This assessment includes 6 subtests, which involve paper and pencil tasks such as line crossing, line bisection, and copying symmetric figures [2]. Most alternative means of neglect assessment also involve paper and pencil tests. However, these tests have several limitations. First, there is high variability in performance on the subtests of paper and pencil tests. For example, individuals may perform well on some tests but poorly on other, very similar tests. Additionally, performance may be affected by how well a person compensates for neglect with head and body movements, limiting our understanding of the actual field of vision being used. Finally, these tests have historically been used primarily as diagnostic tools, with limited work establishing cutoff points for levels of neglect severity. In combination, these limitations lead to lower sensitivity in detecting neglect compared to what is observed during daily tasks.

*Research supported by NSF grant number IIS 1915083 .

Murat Akcakaya is with the Electrical and Computer Engineering Department of the University of Pittsburgh.

II. Methods

Considering the limitations of paper and pencil tests, we introduce an objective EEG-based SN assessment test that overcomes limitations of the traditional tests used to evaluate SN. In particular, to simulate a real-life environment, while EEG acquisition, targets are presented on random locations on a screen with dynamically changing distractors on the background. An EEG-based assessment will provide more detailed data about neglect severity than current methods, providing a map of the visual field being attended to by the patient. Additionally, it can detect the severity of neglect without being influenced by compensatory strategies, which are quickly learned in inpatient settings. Considering these strengths, this assessment approach has the potential to provide a more accurate and detailed diagnostic test for neglect.

III. Results

In the proposed assessment approach, EEG signals are recorded during presentation of visual stimuli in random locations on a screen with a background of dynamically changing distractors. By analyzing data collected from 5 stroke patients with spatial neglect (SN) and 6 stroke patients without spatial neglect, it was found that sensitivity of identifying SN is 88.89% with specificity and overall accuracy of 80.95% and 83.33% respectively. Moreover, experimental results showed that accuracy and specificity of the proposed test are correlated with BIT scores ($R2=0.81$ and 0.83 respectively) of the SN group. Moreover, it was found that the field of view estimated from EEG of the SN group is highly correlated with BIT scores ($R2 = 0.92$).

IV. Discussion & Conclusion

In this paper, we presented a feasibility study for a novel EEG-based SN assessment that has the potential to overcome the most significant weaknesses of current assessment methods. The results are promising, indicating that the EEG-based SN assessment has the potential to detect neglect with 83.33% accuracy, and provide detailed information about the FOV being attended to.

References

[1] K. M. Heilman, E. Valenstein, and R. T. Watson, “Neglect and Related Disorders,” Semin. Neurol., vol. 20, no. 04, pp. 463–470, 2000.

[2] B. Wilson, J. Cockburn, and P. Halligan, “Development of a behavioral test of visuospatial neglect.,” Arch. Phys. Med. Rehabil., vol. 68, no. 2, pp. 98–102, 1987.

Monitoring Hand Use at Home Using Egocentric Video

José Zariffa,
KITE, Toronto Rehabilitation Institute, University Health Network
Institute of Biomaterials and Biomedical Engineering, University of Toronto

***Abstract*— The recovery of upper limb function is often a central priority after neurological injuries. The development of improved interventions for arm and hand function requires the availability of high-quality outcome measures, but options to directly and objectively measure hand use at home are currently limited. Wearable systems based on egocentric cameras and computer vision present the opportunity to evaluate hand function in unconstrained environments with an unprecedented level of detail.**

I. INTRODUCTION

Neurological injuries such as stroke and spinal cord injury (SCI) can result in severe disabilities and limit the affected individual's ability to complete activities of daily living (ADLs) and integrate into the community. Annual costs to the Canadian economy from stroke and traumatic SCI are estimated at \$3.6 billion and \$2.7 billion, respectively [1], [2]. In particular, the impairment of the upper limb (UL) is a major determinant of independence and quality of life after neurological injuries. For instance, an estimated 65% of stroke survivors are unable to complete ADLs as a result of UL impairment [3], while individuals with SCI report that the recovery of UL function is their top priority [4]. Neurorehabilitation strategies that can promote the recovery of UL function are therefore sorely needed. To this end, outcome measures that reflect the true impact of new interventions will be an integral part of the successful translational process.

There is a demonstrated disconnect between the UL functional capacity demonstrated in the clinic and the actual performance of ADLs using that limb in daily life [5]. Wearable technology promises to play an important role in filling this gap, but the focus to date has been on wrist-worn accelerometry, which reflects arm movements while providing limited direct information about hand function.

Video from wearable cameras ("egocentric video") constitutes an alternative means to measure hand function at home [6]. These videos provide a very rich source of data about the hand, the objects that it interacts with, and the grasping strategies involved. The large amount of data generated calls for machine learning strategies to automatically extract clinically meaningful information.

This work was supported in part by the Natural Sciences and Engineering Research Council of Canada (RGPIN-2014-05498), the Rick Hansen Institute (G2015-30), the Ontario Early Researcher Award (ER16-12-013), the Craig H. Nielsen Foundation (542675), and the Heart and Stroke Foundation of Canada (G-18-0020952).

J. Zariffa is with KITE – Toronto Rehab – University Health Network, Toronto, ON, CA and the Institute of Biomaterials and Biomedical Engineering (IBBME), University of Toronto, Toronto, ON, CA (email: jose.zariffa@ utoronto.ca)

II. METHODS

Video datasets have been collected to date from 20 able-bodied individuals, 17 individuals with SCI and 6 stroke survivors in a home simulation environment, as well as in the homes of 9 individuals with SCI and 6 stroke survivors (GoPro Hero 4 and 5, GoPro, San Mateo, CA, USA).

Using labeled datasets from these videos, problems addressed to date include: (1) Hand detection in egocentric video using deep learning-based object detectors retrained on our datasets of impaired hands performing a variety of ADLs. (2) Detection of interactions between hands and objects in the environment, and extraction of summary metrics such as the number and duration of interactions. (3) Hand pose estimation in egocentric video.

III. RESULTS

Hand detection has been achieved with F1-scores of 0.89 ± 0.06 [7], and interaction detection with F1-scores of 0.74 ± 0.15 and 0.73 ± 0.15 (left/right hand) [6]. Pose estimation is opening the door to new applications.

IV. DISCUSSION & CONCLUSION

Early results suggest that egocentric video has the potential to have a transformative impact on how hand function is tracked and quantified in unconstrained environments in the context of neurorehabilitation.

REFERENCES

[1] M. Arango and C. Bancej, *Tracking Heart Disease and Stroke in Canada 2009.* Public Health Agency of Canada, 2009.
[2] H. Krueger *et al*, "The economic burden of traumatic spinal cord injury in Canada," *Chronic Dis Inj Can,* vol. 33, *(3),* pp. 113-122, 2013.
[3] P. S. Lum *et al*, "Gains in upper extremity function after stroke via recovery or compensation: Potential differential effects on amount of real-world limb use," *Topics in Stroke Rehabilitation,* vol. 16, *(4),* pp. 237-253, 2009.
[4] K. D. Anderson, "Targeting recovery: priorities of the spinal cord-injured population," *J. Neurotrauma,* vol. 21, *(10),* pp. 1371-1383, October, 2004.
[5] K. J. Waddell *et al*, "Does Task-Specific Training Improve Upper Limb Performance in Daily Life Poststroke?" *Neurorehabil. Neural Repair,* pp. 1545968316680493, 2016.
[6] J. Likitlersuang *et al*, "Egocentric video: a new tool for capturing hand use of individuals with spinal cord injury at home," *J Neuroeng Rehabil,* vol. 16, *(1),* pp. 83, 2019.
[7] R. J. Visée, J. Likitlersuang and J. Zariffa, "An Effective and Efficient Method for Detecting Hands in Egocentric Videos for Rehabilitation Applications," *arXiv,* pp. 1908.10406, 2019.

Sleep Apnea Diagnosis using Wearable Technologies

Azadeh Yadollahi, KITE-Toronto Rehabilitation Institute, University Health Network

***Abstract*— Sleep apnea is a chronic respiratory disorder, whose standard assessment requires full night in-laboratory polysomnography. However, polysomnography is expensive, time consuming, and inconvenient. On the other hand, sleep apnea can be assessed using more convenient wearable devices. This study investigates the feasibility of respiratory event detection and sleep apnea severity estimation by analyzing respiratory related sounds and movements.**

V. INTRODUCTION

Sleep apnea is a common respiratory disorder that occurs in 10% of the adult population. Sleep apnea occurs due to complete (apnea) or partial (hypopnea) cessations of breathing during sleep. Sleep apnea has been shown to increase the risk of heart disease by 3 fold, stroke by 4 fold, and car accidents by 7 fold. In practice, the severity of sleep apnea is quantified by the Apnea Hypopnea Index (AHI), which is the number of apneas and hypopneas per hour of sleep. Currently, the gold standard to measure AHI is an overnight polysomnography (PSG) performed in a sleep laboratory. However, PSG is inconvenient [9], expensive, and time consuming. Consequently, about 85% of the population with sleep apnea remain undiagnosed.

Our objective is to develop novel methods based on respiratory sounds and movement to estimate sleep apnea severity with high accuracy. We have developed a range of algorithms based on machine learning to extract several morphological features from respiratory related sounds and movements to detect respiratory events, and additionally estimated the AHI.

VI. METHODS

Adult participants referred to the sleep laboratory at Toronto Rehabilitation Institute for overnight sleep studies were included. Simultaneously with the polysomnography, an accelerometer was attached to the participant's suprasternal notch to record respiratory related movements. More than thirty features were extracted from the tracheal sounds and movements and used in a deep learning classifier to detect respiratory events. The apnea hypopnea index (AHI) was estimated by counting the number of detected events per hour of sleep.

* This work was funded by grants from NSERC RGPIN-2016-06549 and RGPIN-435653, OCE VIPII Project #25510, FedDev Ontario, and by BresoTEC Inc.

VII. RESULTS

Figure 1.a shows the correlation between estimated AHI and PSG-derived AHI both calculated according to total recording time. The correlation *r*-value was 0.86 with p<0.0001. Bland-Altman limits of agreement were −25.5 to 28.9 (mean=1.7, Figure 1b). According to the analysis, most of the subject values were located within the 95% confidence interval. For AHI cut-off thresholds of 10, 15, 20, and 30 AHI estimation accuracies were 0.80, 0.84, 87, and 0.88 respectively.

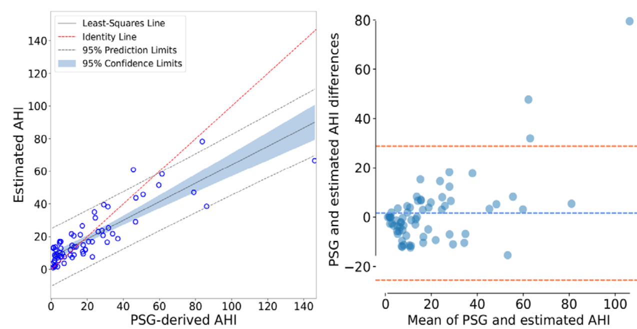

Fig. 1. (a) Correlation between estimated AHI and simultaneous PSG-derived AHI in 69 subjects. (b) Bland-Altman limits of agreement between estimated AHI and simultaneous PSG-derived AHI in 69 subjects. The upper and lower red lines indicate the mean ±1.96 SD

We found similar results in detecting sleep apnea based on respiratory sounds analysis.

VIII. DISCUSSION & CONCLUSION

In this study, we have proposed a series of features to quantify changes in the tracheal movement associated with respiratory events. We developed a novel approach using deep learning classifier to detect respiratory events from respiratory related movement signals and to estimate the AHI. Our proposed method based on accelerometer and deep learning can be implemented as a cost-effective, lightweight, and reliable wearable portable device for home-based sleep apnea monitoring. The technology has the potential to address the under-diagnosis problem of the sleep apnea.

Longitudinal Monitoring of Gait and Fall Risk in Natural Settings

B. Taati, K-D. Ng, S. Mehdizadeh, A. Sabo, A. Mansfield, A. Flint, A. Iaboni
KITE | Toronto Rehabilitation Institute – University Health Network

Abstract— **Falls are a leading cause of injury, loss of independence, reduced quality of life, and mortality in older adults with dementia. Many falls can be prevented if clinicians could determine a person's risk of falling and offer an intervention to reduce the risk. Unfortunately, existing tools for measuring falls risk are not appropriate for people with dementia, or are of limited value because they are not sensitive to changes in fall risk over time. To provide a clear opportunity to intervene and reduce the risk of falling, we need a tool that can detect subtle changes in falls risk and can predict falls in the short-term, i.e. days or weeks. We developed a tool which measures walking patterns using a wall-mounted camera. Using this system, we monitor the mobility of people with dementia frequently and unobtrusively. We use this information to identify patterns of mobility, and changes in patterns of mobility, that occur in the days or weeks before a fall.**

I. Introduction

As many as 60% of older adults with dementia fall each year, many of whom sustain injuries as a result. Recent advances in computer vision sensing technology and in machine learning algorithms offer a potential solution; namely to identify and to attend to individuals whose risk of falling is rapidly increased in the short term. Acute changes in gait and dynamic stability are predictive of falls in the short-term (days to weeks). For example, new medications, failing health, and declines in cognition detectably alter falls risk in the time immediately preceding a fall. Frequent falls risk assessments by a clinician would be time consuming and, therefore, not feasible. Our ambient monitoring solution (called AMBIENT) allows for the frequent, accurate, unobtrusive, and cost-effective measurement of gait and balance parameters. We are working on validating AMBIENT as a falls risk assessment tool for individuals with moderate to severe dementia. The system automatically monitors LTC residents' gait as they walk in front a sensor during their daily routine, and estimates short-term changes in fall risk. The primary users of the solution will be the designated care staff who will receive automatically generated fall risk alerts through electronic medical record or via email.

II. Methods

In a pilot study to establish feasibility, we collected baseline and longitudinal data from 20 long-term residents with dementia, including mobility parameters (captured via AMBIENT) and falls data [1]. This study demonstrated the feasibility of longitudinal tracking of gait in a dementia inpatient setting using AMBIENT. Subsequently, in experiments with N=52 participants with dementia, we demonstrated that baseline parameters of gait, i.e. averaged over the first two weeks of stay after admission, were significantly associated with the number of falls during admission [2]. Whereas a 3D sensing device was used in these two studies, we now demonstrate that regular cameras could be used in conjunction with computer vision models for real-time human pose tracking. Specifically, we use vision-based pose tracking models to detect and track walking movements of residents in a long-term care facility and extract gait features from tracked pose sequences of each walking bout.

III. Results

Results indicate that baseline parameters of gait measured from human pose tracking in video data explain ~60% of the variance in the number of future falls experiences by participants [3].

IV. Discussion & Conclusion

Gait variables calculated from human pose tracking in video data are significantly associated with future falls in long-term care residents with dementia. We are currently developing machine learning models to analyse longitudinal chances in gait and dynamically estimate and update short-term fall risk, e.g. the probability that a resident will fall within the next 7 or 30 days. Such a system will allow preventative measures to be taken to reduce falls and fall related injuries.

References

[1] Dolatabadi E, Zhi YX, Flint AJ, Mansfield A, Iaboni A, Taati B. The feasibility of a vision-based sensor for longitudinal monitoring of mobility in older adults with dementia. Archives of gerontology and geriatrics. 2019 May 1;82:200-6.

[2] Mehdizadeh S, Dolatabadi E, Ng KD, Mansfield A, Flint A, Taati B, Iaboni A. Vision-based assessment of gait features associated with falls in people with dementia. The Journals of Gerontology: Series A. 2019 Aug 20.

[3] Ng KD, Mehdizadeh S, Iaboni A, Mansfield A, Flint A, Taati B. Human Pose Estimation to Assess Gait and Fall Risk in Older Adults with Dementia. Under review (2019).

* This work was supported in part by the Alzheimer's Association & Brain Canada (New Investigator Research Grant NIRG-15-364158), by the DescriptionThe Natural Sciences and Engineering Research Council of Canada (NSERC), by FedDev Ontario, by the Toronto Rehabilitation Institute, by an Academic Scholars Award from the Department of Psychiatry, University of Toronto (AI), by a Canadian Institutes of Health Research New Investigator Award, by the AGE-WELL Canada's Technology and Aging Network, and by the Walter and Maria Schroeder Institute for Brain Innovation and Recovery.