Instrumented Timed Up and Go:

Fall Risk Assessment based on Inertial Wearable Sensors

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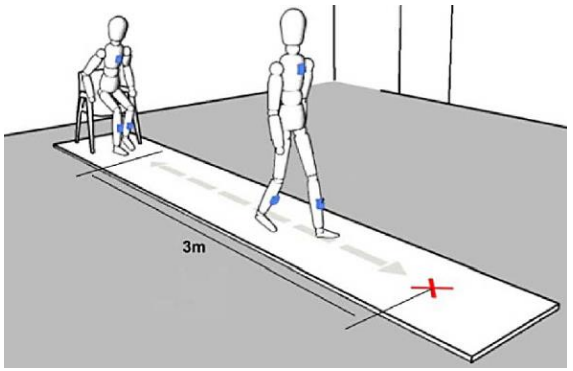
1. Introduction

Motivation

Fall Risk Assessment

- Current solutions
  - Only evaluate one type of risk factor
  - Are applied individually
  - Observational and subjective assessment
  - Lack of a standard assessment protocol

- Proposed solution
  - Instrumentation of standard test with wearables
  - Evaluate multiple components of traditional tests
  - Additional quantitative information form tests
  - Reliable and reproducible output



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1. Introduction

Fall Risk Assessment

Traditional Time-Up and Go Test

- Total time to perform the test is recorded
  - Reported to be predictive of fall with 81% sensibility and 39% specificity

Instrumented Time-Up and Go Test

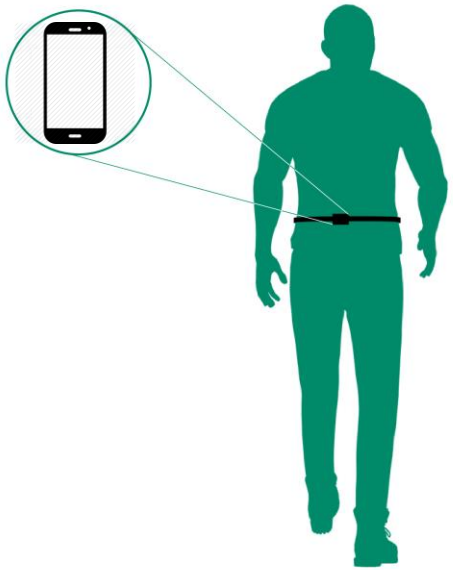
- Analysis of each component of the test (stand, walk, turn, walk back and sit)
- Salarian et al.
  - iTUG to access mobility in Parkinson patients with 7 IMU
- Greene et al.
  - iTUG to extract temporal and angular velocity parameters with 2 inertial sensors
- Purpose of this study
  - iTUG to extract meaningful features from smartphone built-in IMU

2. Methods

Data collection

Group statistics

- 18 community-dwelling older adults
- Average age of 73±5 years old
- Body mass index (BMI) of 26.7±4 kg/m2
- 5 males



Setup

- Inertial sensors of smartphones
  - Sampled at 200Hz
  - Placed in pocket or waist

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2. Methods

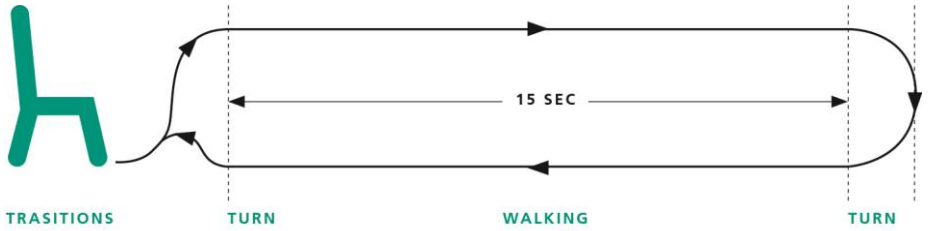
Protocol

Questionnaires

- Iconographic Falls Efficacy Scale (FES) *evaluates fear of falling in performing daily activities*
- Medical History *questionnaire about chronic diseases, vision, audition, exercise profile*
- History of falls *in the last 12 months*

Functional Tests

- Tinetti Performance Oriented Mobility Assessment (POMA) *assess gait and balance abilities*
- Time-Up and Go Test (TUG) *measures the time to stand up, walk 3m, turn back and sit*
- instrumented TUG *measures mobility parameters during stand, 30 sec walk and sit*



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2. Methods

Data Processing

Automatic Segmentation

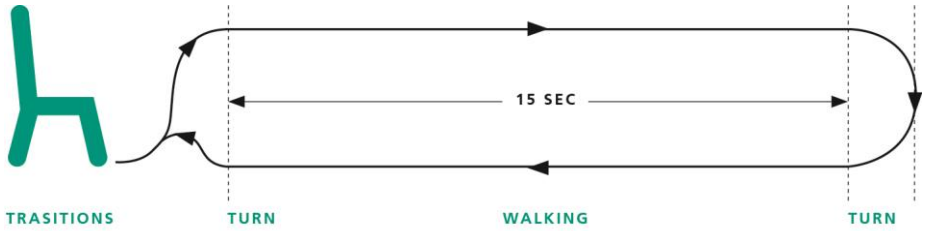
- Accelerometer & Gyroscope processing
- Divide in 5 segments: stand, walk, turn, walk back and sit

Feature Extraction

- Accelerometer magnitude signal
- Statistical and frequency features

Statistical Analysis

- t-test (5% significance level) to compare means between groups of higher and lower fall risk



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3. Results

Standard Tests Results

Participant	Number of falls in previous 12 months (> 2 → Higher Risk)	Iconographic Tinetti FES (> 70 → Higher Risk)	Tinetti POMA (< 25 → Higher Risk)	TUG time (seconds) (≥ 14 → Higher Risk)
1	1	13	26	14.5
2	0	27	25	15.7
4	6	67	23	13.6
6	1	0	24	9.4
8	3	23	25	9.2
9	0	0	26	12.3
10	2	20	24	10.6
12	0	17	26	13.0
13	0	20	26	18.0
15	0	0	26	14.0
16	0	10	26	10.4
17	1	0	26	10.0
18	0	0	27	7.0
3	5	100	9	40.5
5	1	87	7	41.2
7	0	20	20	19.9
11	0	30	24	19.0
14	0	60	20	14.0

Higher Risk

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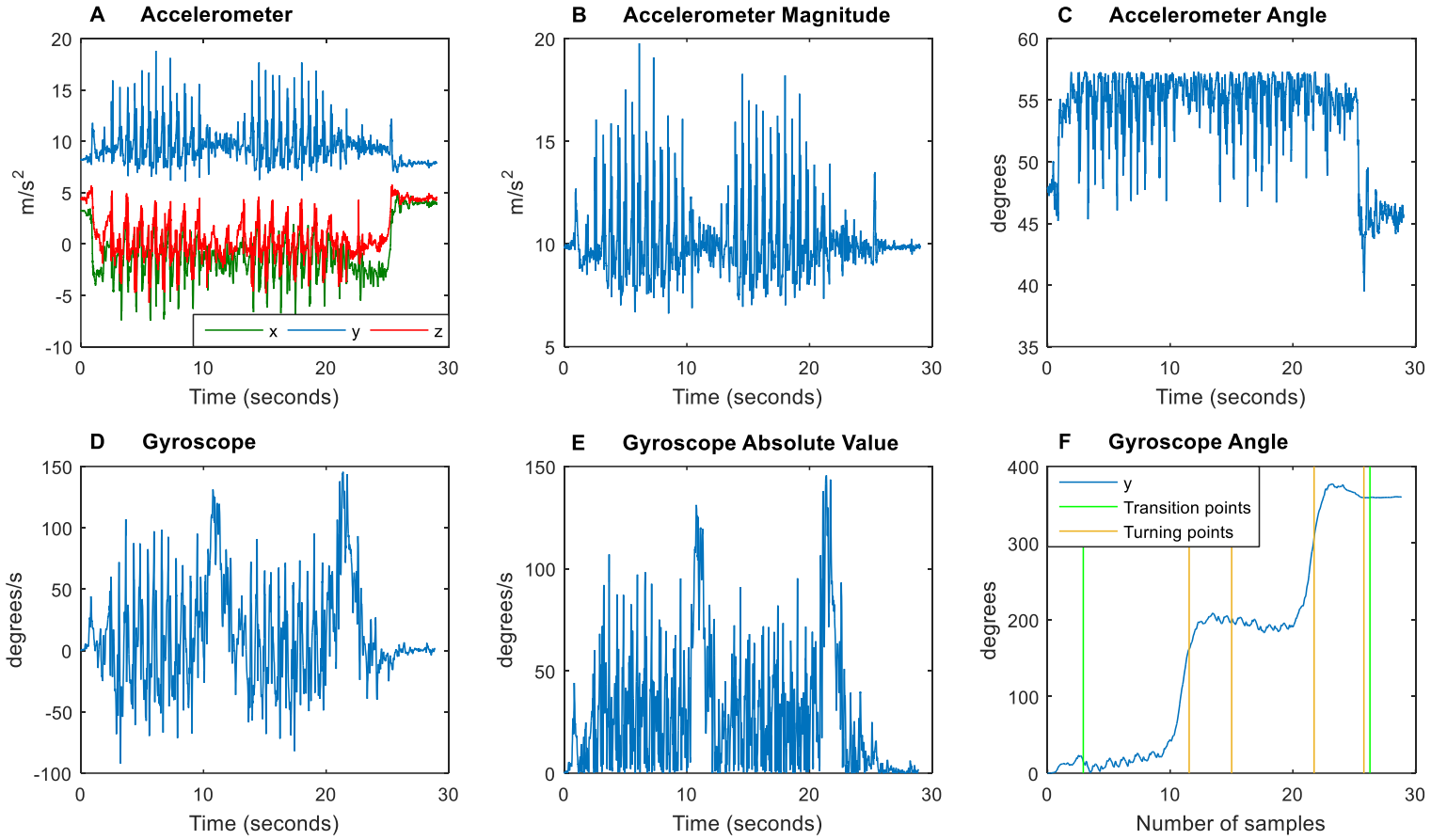
3. Results

iTUG Automatic Segmentation



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3. Results

iTUG Features *(walk & turn segments)*

Statistical Features

- Magnitude Signal
  - Number of times the magnitude signal crosses the mean value (MeanCrossCount)
  - Inter quartile range (IQR)
  - Energy
  - Entropy
  - Standard deviation (Stdev)
  - Mean value
  - Median deviation (MedianDev)
  - Root mean square (RMS)
  - Skewness
  - Kurtosis
  - Average value of minimum and average value of maximum (MinAvg and MaxAvg)
  - Difference between MaxAvg and MinAvg (AvgPeak Height)

Frequency Domain Features

- FFT of the Magnitude Signal
  - Maximum amplitude (FFT Max Amp)
  - Second maximum amplitude (FFT 2nd Max)
  - The ratio (FFT Amp scale)
  - Difference (FFT Amp dif)

3. Results

Statistical Significance

Feature	Low Risk[a]	High Risk[a]	p-Value[b]	Segment
RMS	10,55± 0,35	10,20 ± 0,16	0,05	
Stdev	2,32 ± 0,67	1,47 ± 0,40	0,02	
MedianDev	1,21± 0,31	0,54 ± 0,30	0,00	
IQR	2,52 ± 0,62	1,13 ± 0,66	0,00	
Skewness	0,89 ± 0,53	2,42 ± 1,24	0,00	
Kurtosis	1,97 ± 2,55	13,72 ± 9,61	0,00	
MeanCrossCount	86,23 ± 23,62	135,80 ± 67,90	0,03	Walk
FFT Max Freq	1,67 ± 0,23	3,47 ± 2,86	0,03	
FFT 2nd Max Freq	3,48 ± 1,50	5,53 ± 2,31	0,04	
FFT Max Amp	1,61 ± 0,53	0,65 ± 0,36	0,00	
FFT 2nd Max	0,76 ± 0,22	0,50 ± 0,24	0,04	
FFT Amp scale	2,12 ± 0,51	1,26 ± 0,10	0,00	
FFT Amp dif	0,84 ± 0,42	0,15 ± 0,12	0,00	
Stdev	1,91 ± 0,93	0,80 ± 0,27	0,02	
Median Dev	1,06 ± 0,76	0,31± 0,22	0,05	
IQR	2,15 ± 1,50	0,66 ± 0,47	0,05	
MinAvg	6,72 ± 0,94	8,22 ± 0,24	0,00	
MaxAvg	13,97 ± 2,10	11,91± 0,53	0,05	
AvgPeak Height	7,25 ± 2,83	3,70 ± 0,74	0,02	Turn
Energy	59803,05 ± 23109,31	98759,52 ± 33372,40	0,01	
Entropy	8,81 ± 0,92	9,83 ± 0,51	0,03	
Kurtosis	2,50 ± 3,10	10,54 ± 8,98	0,01	
MeanCrossCount	27,69 ± 13,01	73,20 ± 41,25	0,00	
FFT 2nd Max	0,70 ± 0,30	0,27 ± 0,11	0,01	

[a] Mean ± standard deviation
[b] Significance level of 5%

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4. Conlcusions

- The TUG test was instrumented with wearable **inertial sensors**.
- Three phases of the TUG were automatically segmented (stand, walk and turn).
- Statistical and frequency domain features were extracted for each segment.
- Overall, features from the **walking and turning phases** present different groups of high and low fall risk.
- This study indicates that the iTUG is a viable tool for fall risk assessment, with potential to be implemented in clinical or hospital environments.
- The test is quick and the instrumentation is easy and do not require any specialized technician to perform it.

4. Future Work

FallSensing

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a greater step

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