Proposal of Final Project
Fall Detection with CNN

Intro to Computer

Panel 15

Paper Review

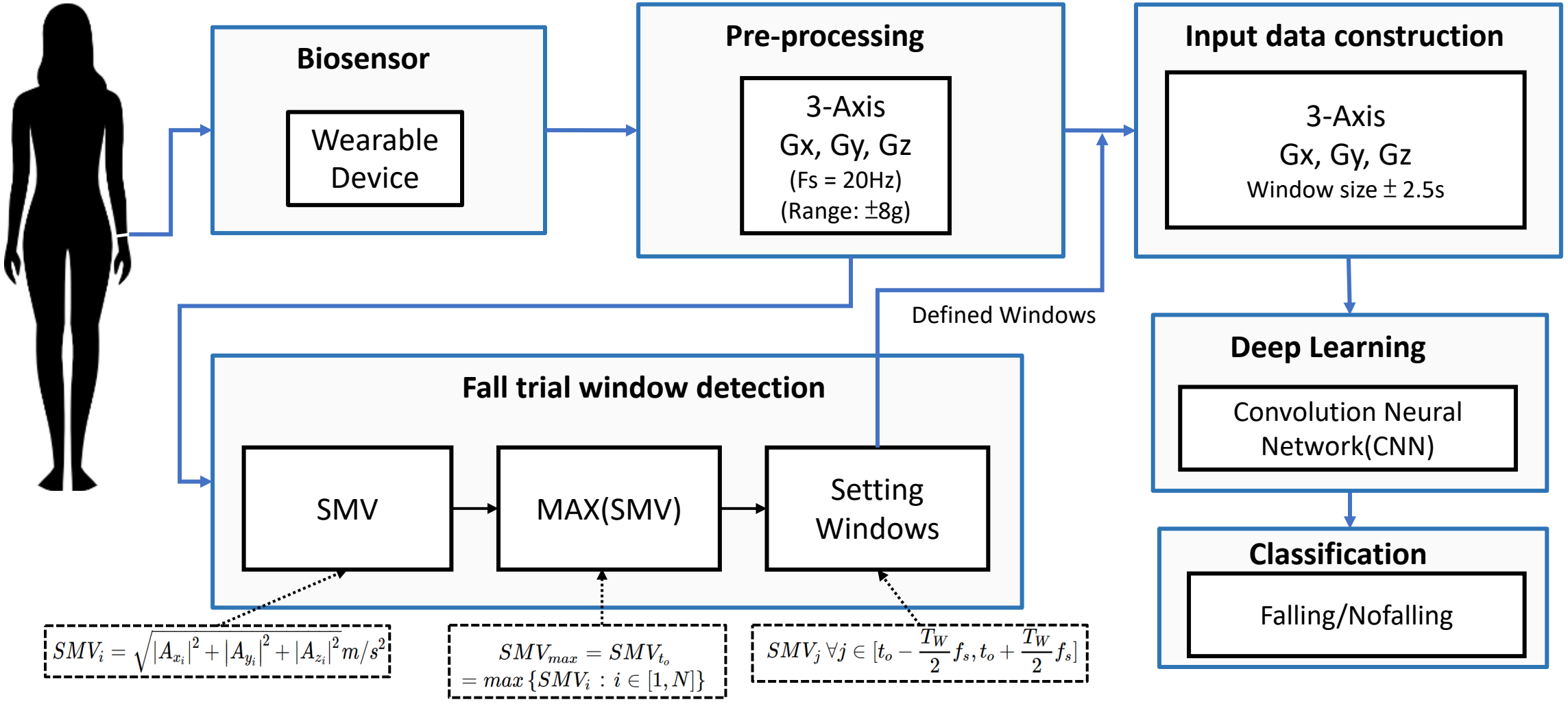
Author	Year	Dataset	Sensitivity	Specificity
Poorani et al	2012	Not specified dataset obtained from UCI machine learning repository	91%	n.i.
Özdemir & Turan.	2016	Erciyes University	94.20%–96.27% (Accuracy)	
Khojasteh et al.	2018	UMAFall, DaLiAC, Epilepsy & FARSEEING	83.33%–100%	80.13%–84.18%
Mauldin et al.	2018	FARSEEING, Smartwatch and Notch	89%–100%	70%–99%
Chelli & Patzold	2019	Cogent Labs	96.8%–99.11%	100%
Wisesa & Mahardika	2019	UMAFall	23.6%–100%	74.1%–97.6%

Dataset Selection

Dataset	Gender (Female/Male)	Age	Number of types(ADLs/Fallings)	Number of samples(ADLs/Fallings)	Duration of samples
UMAFall	17 (7/10)	[18–55]	8/3	531 (322/209)	15 s (all samples)
FARSEEING	15 (8/7)	[56–86]	0/22	22 (0/22)	1200
UniMiB SHAR	30 (24/6)	[18–60]	9/8	7013 (5314/1699)	1 s (all samples)
IMUFD	10 (n.i.)	n.i.	8/7	600(390/210)	[15–20.01]
DU	10 (4/6)	[17–20]	8/2	3299 (2309/990)	[2.85–11.55]
Smartfall	7 (n.i.)	[21–55]	4/4	181 (90/91)	[0.576–16.8]
Smartwatch	7 (n.i.)	[20–35]	7/4	2563 (2456/107)	[1–3.776]
UP-Fall	17 (8/9)	[18–24]	6/5	559(304/255)	[9.409–59.979]
DOFDA	8 (2/6)	[22–29]	9/9	432 (120/312)	1.96–17.262

Dataset Selection

Dataset	Number of Sensing Points	Captured Signals in Each Sensing Points	Positions of the Sensing Points	Type of Device	Sampling Rate (Hz)	Range
TST Fall detection	2	1 (A)	Waist, Wrist	2 external IMUs	100	±8 g (A)
Erciyes University	6	3(A, G, M)	Chest, Head, Ankle, Thigh, Wrist, Waist	6 external IMUs	25	±16 g (A) ±1200°/s (G) ±150 μT (M)
Gravity Project	2	1 (A)	Thigh (smartphone in a pocket) Wrist (smartwatch)	1 smartphone 1 smartwatch	50	±2 g (A) ±16 g (A)
UMAFall	5	3(A, G, M)	Ankle, Chest, Thigh, Waist Wrist	1 Smartphone 4 external IMUs	100 (SP) 20 (IMUs)	±16 g (A) ±256°/s (G) ±4800 μT (M)
DU-MD	1	1 (A)	Wrist	1 external IMU	33	±4 g (A)
Smartwatch	1	1 (A)	Wrist (left hand)	Smartwatch (MS Band)	31.25	±8 g (A)
Notch	1	1 (A)	Wrist	1 external IMU	31.25	±16 g (A)
UP-Fall	5	2 (A, G)	Ankle, Neck, Thigh (pocket) Waist, Wrist	5 external IMUs	14	±8 g (A) ±2000°/s (G)


Biosensor
Wearable Device
Pre-processing
3-Axis
Gx, Gy, Gz
(Fs = 20Hz)
(Range: ±8g)
Input data construction
3-Axis
Gx, Gy, Gz
Window size ± 2.5s
Defined Windows
Fall trial window detection
SMV
MAX(SMV)
Setting Windows
Deep Learning
Convolution Neural Network(CNN)
Classification
Falling/Nofalling
$SMV_i = \sqrt{|A_{x_i}|^2 + |A_{y_i}|^2 + |A_{z_i}|^2} m/s^2$
$SMV_{max} = SMV_{t_o} = max\{SMV_i : i \in [1, N]\}$
$SMV_j \, \forall j \in [t_o - \frac{T_W}{2} f_s, t_o + \frac{T_W}{2} f_s]$

Classification of UP

Falling

- Falling forward using hands
- Falling forward using knees
- Falling backwards
- Falling sideward
- Falling when sitting down, loss of balance

No falling

- Walking
- Standing
- Sitting
- Picking up an object
- Jumping
- Laying

Classification of UCI

Falling

- Falling forward to the floor
- Falling forward to the floor with arm protection
- Falling down on the knees
- Falling down on the knees, lying on the floor
- Falling on the floor and quick recovery
- Falling on the floor and slow recovery
- Falling down, ending in right lateral position
- Falling down, ending in left lateral position
- Falling, ending sitting
- Falling, ending lying
- Falling, ending lying in right lateral position
- Falling, ending lying in left lateral position
- Falling, ending lying
- Falling with subsequent recovery
- Rolling out of bed and going on the floor
- Standing on a podium going on the floor
- Falling, following a vertical trajectory
- Falling down slowly slipping on a wall

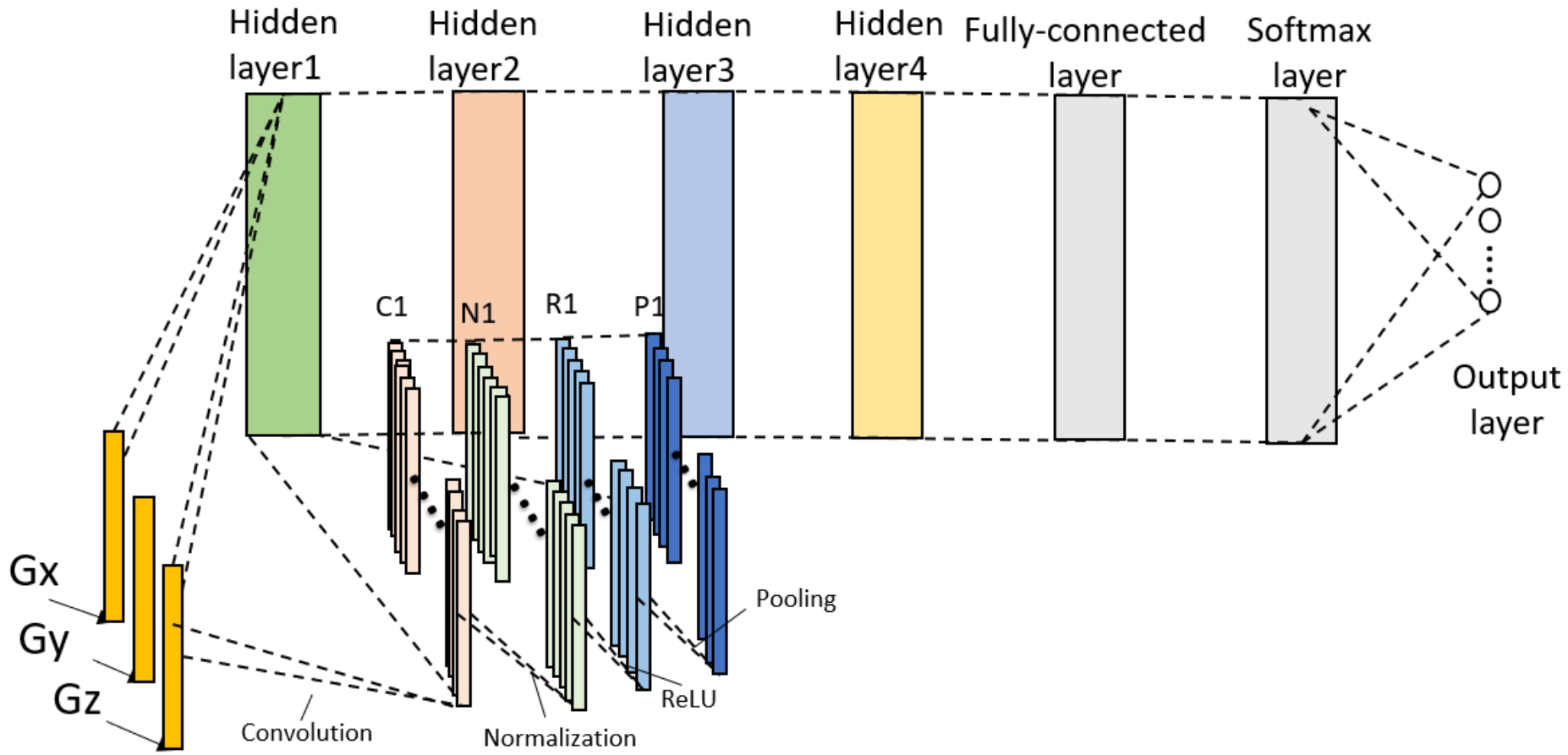
No falling

- Walking forward
- Walking backward
- Running
- Squatting, then standing up
- Bending about 90 degrees
- Bending to pick up an object on the floor
- Walking with a limp
- Stumbling with recovery
- Bending while walking and then continuing walking
- Coughing or sneezing
- Sitting with a certain acceleration onto a chair (hard surface)
- Sitting with a certain acceleration onto a sofa (soft surface)
- Sitting in the air exploiting the muscles of legs
- Sitting with a certain acceleration onto a bed (soft surface)
- From vertical lying on the bed
- From lying to sitting

Our Classification

Number	Activity	Explanation	Order	Selected in datasets
Activity 1	Walking	連續走動10秒	1	UP
Activity 2	Falling forward using hands	走動(默數4秒)，往前跌並用手支撐，保持跌倒的姿勢	10	UP/UCI
Activity 3	Sitting	由站立(默數4秒)狀態做下椅子上靜止不動	2	UP
Activity 4	Falling backwards	走動(默數4秒)，往後跌並保持跌倒的姿勢	11	UP
Activity 5	Picking up an object	站立(默數4秒)彎腰(默數3秒)撿東西後站起	3	UP
Activity 6	Falling sitting in empty chair	走動(默數4秒)，往正下方座倒並保持跌倒的姿勢	12	X
Activity 7	Rolling on bed	在床上躺著(默數4秒)翻滾變換睡姿	4	X
Activity 8	Stretch	站立(默數4秒)，伸懶腰	5	X
Activity 9	Beat the table	手放在桌上(默數4秒)，用力拍打桌子	6	X
Activity 10	Jumping	連續輕跳10秒	7	UP
Activity 11	Falling forward using knees	走動(默數4秒)，往前跌並以膝蓋著地，保持跌倒的姿勢	13	UP/UCI
Activity 12	Standing	坐在椅子上(默數4秒)站起保持不動	8	UP
Activity 13	Falling sideward	走動(默數4秒)，往側邊跌並保持跌倒的姿勢	14	UP
Activity 14	Laying	由坐姿(默數4秒)慢慢躺下	9	UP
Activity 15	Falling caused by fainting	走動(默數4秒)，全身保持放鬆並倒下不動	15	X

Methods


Hidden layer1
Hidden layer2
Hidden layer3
Hidden layer4
Fully-connected layer
Softmax layer
C1
N1
R1
P1
Output layer
Gx
Gy
Gz
Convolution
Normalization
ReLU
Pooling

Parameters

Table 5. Architecture and training hyper-parameters of the employed CNN.

Training algorithm	Stochastic Gradient Descent Momentum
Error function	Cross-entropy loss function
Maximum number of training epochs	20
Mini-batch size (to estimate the gradient of the loss in every iteration)	64 training instances
Validation frequency	1 epoch
Validation patience	3
Tecniques to prevent overfitting	Cross-validation, L2 Regularization and dropout layers
Initial learning rate:	0.0001
Layers activation functions	ReLU (hidden layers) and *softmax* (output layer)
Number of convolutional feature extraction layers	4
Sub-layers for every feature extraction layer	4 (1 convolutional, 1 normalization, 1 ReLU and 1 max pooling layers)
Number of filters for each convolutional layer	16 (1st layer), 32 (2nd), 64 (3rd), 128 (4th)
Filter size (for all convolutional layers)	1×5
Size of zero-padding	2 samples
Stride	1×1 ("non-strided")
Pool size of the max-pooling layer	1×5
Classification layers	1 fully-connected layer, 1 softmax layer and 1 final classifier

Thanks for Listening

by personnel of Panel 15