FPGA-based fall detection system using millimeter-wave radar and convolutional neural network

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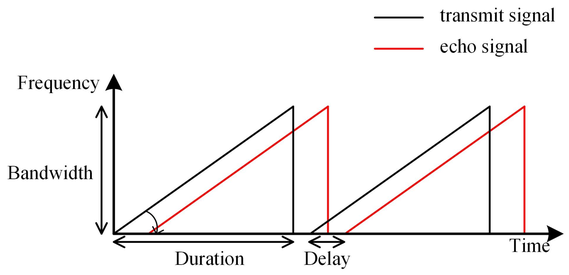
2022 ICEICT

Introduction

In frequency modulated continuous wave (FMCW), the received echo frequency is the same as the transmitted frequency, which is a triangular wave law, but there is a time difference. The target distance can be calculated by using this time difference, which can be used for fall detection.



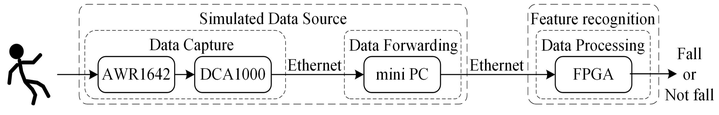
Problem

Conventional fall detection systems based on millimeter wave radar process data in computers, which have the following disadvantages:

- Poor stability of software system
- Slow processing speed
- Hard to miniaturize

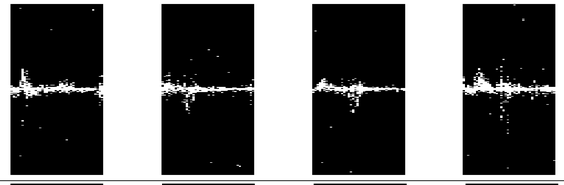
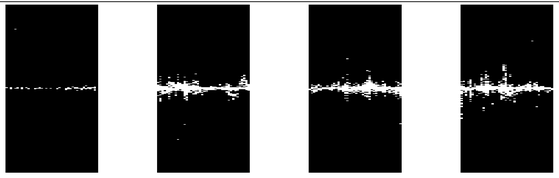
FPGA-based system

FPGA processes raw data and realizes feature recognition. Due to the limitation of radar equipment, PC is used to forward data here.



Data processing

The image obtained from the raw data through downsampling, STFT, and binarization is as follows:

Feature	Feature map
Fall	
Not fall	

Feature recognition

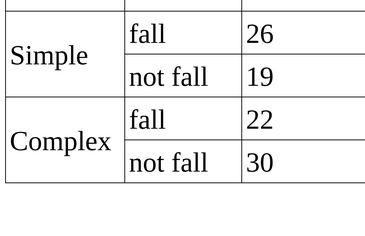
Based on the above feature map dataset, convolutional neural network (CNN) is trained in Python, and its structure is shown below. The same network structure is built in FPGA, and the trained weight coefficients can be input in order to realize the migration of the network to FPGA.

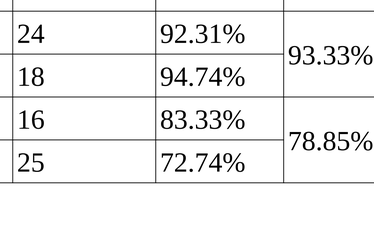
Layer	Layer type	Kernel size	Stride	Output
0	Input	-	-	[256, 42]
1	Convolutional	[4, 3, 3]	1	[4, 254, 40]
2	Max Pooling	-	2	[4, 127, 20]
3	Convolutional	[4, 3, 3]	1	[4, 125, 18]
4	Max Pooling	-	2	[4, 62, 9]
5	Convolutional	[4, 3, 3]	1	[4, 60, 7]
6	Max Pooling	-	2	[4, 30, 3]
7	Fully Connected	-	-	128
8	Fully Connected	-	-	2

Experiment

The test prototype and experimental environment are shown below.

When the tester makes a simple or complex posture movement in the detection area, the FPGA controls the buzzer to alarm when a fall occurs.





The experimental results show that the system has a high detection accuracy for the fall motion of simple posture, while it is easy to misjudge the movement of complex posture, especially the non-fall motion. The detection accuracy can be improved with the further design of the CNN.

Posture	Feature	Number of Samples	Number of Accurate Predictios	Accuracy Rate	Summary
Simple	fall	26	24	92.31%	93.33%
	not fall	19	18	94.74%	
Complex	fall	22	16	83.33%	78.85%
	not fall	30	25	72.74%	