UNIROBOTICS

Simplified Detection Mechanism

Smart Firearm

Contents

Executive Summary

Smart Firearm System is a training module that monitor and analyze behavior of the shooter while shooting, holster draw drilling and other drills. This document explains the basic version of detection algorithm that avoids sensor fusion implementation to simplify the integration processes. Explained procedures are used for trigger, cooking and charger loading detections.

Definitions

X_{axis} : Vector containing data acquired from accelerometer x axis, vector size 50x1.

Y_{axis} : Vector containing data acquired from accelerometer y axis, vector size 50x1.

Z_{axis} : Vector containing data acquired from accelerometer z axis, vector size 50x1.

Mathematical background for detection algorithms

Step 1

Define 3 examination windows (n by 1 array) for every accelerometer axis, the signal within these windows will be utilized to detect if the signal at time t can be classified.

The minimum of the window size must be chosen such that the signal window size is sufficiently big to contain the in minimum amount of data points that describe the guns motion; noting that the window size depends on the acquisition frequency of the smart fire arm module which is set at 400 Hz, the window size is chosen to be equal to 50 sample points and the loop iteration speed is set such that at every iteration 15 new data point are added to the beginning of the vector that presents the detection window.

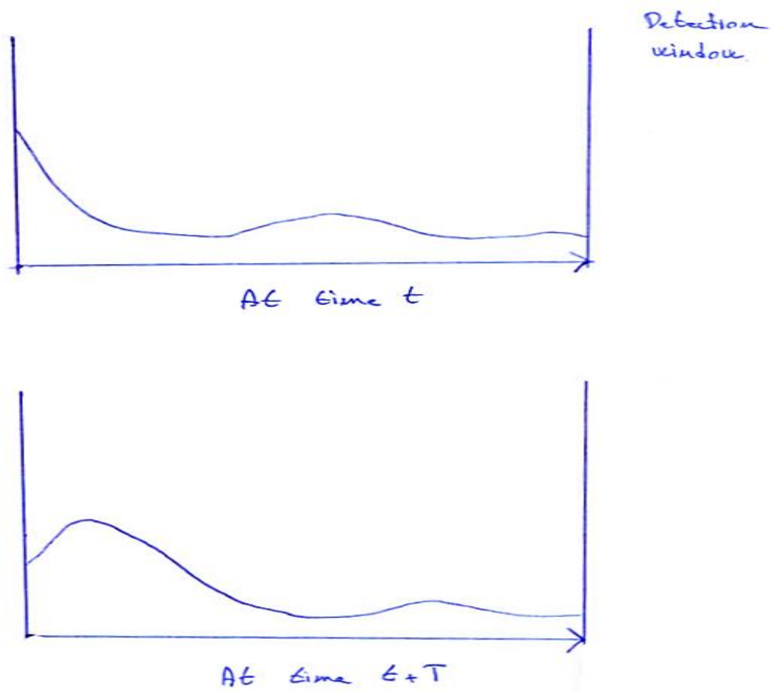


Figure 1: Detection window Updating

Step 2

Giving the three predefined detection (vector) windows the following variable name:

$X_{axis}, Y_{axis}, Z_{axis}$

- Calculate norm vector effecting on the three axes:

$V = \mathrm{X}_{\mathrm{axis}}^{\mathrm{T}} X_{axis} + \mathrm{Y}_{\mathrm{axis}}^{\mathrm{T}} Y_{axis} + \mathrm{Z}_{\mathrm{axis}}^{\mathrm{T}} Z_{axis}$

$V = V/1000$ (Rescaling)

$V_{sort} = sortbydescending(V)$

$V_{average\_max} = average(V_{sort}(1:5))$

$V_{mean} = mean(V)$

$V_{std} = standart\_deviation(V)$

- Calculate the maximum level of excitation at every axis

$X_{sorted} = sortbydescending(\, X_{axis})$

$X_{average\_max} = average(\, X_{sorted}(1:5))$

$Y_{sorted} = sortbydescending(\, Y_{axis})$

$$Y_{average\_max} = average(\ Y_{sorted}(1:5))$$

$$X_{absolute\_sorted} = sortbydescending(\ abs(X_{axis}))$$

$$X_{abs\_average\_max} = average(\ X_{absolute\_sorted}(1:5))$$

$$Y_{absolute\_sorted} = sortbydescending(\ abs(Y_{axis}))$$

$$Y_{abs\_average\_max} = average(\ Y_{absolute\_sorted}(1:5))$$

Cooking detection

To detection cooking action the following set of conditions is used.

Conditions Set 1

The first three conditions indicates that the gun has experienced a high excitation when the firearm has been loaded. Specially cond3 is used to detect the level of vibrations it has been under.

$$cond\ 1\ = V_{average\_max}\ >\ 5000\ (mg)$$

$$cond\ 2\ = V_{mean}\ >\ 1000\ (mg)$$

$$cond\ 3\ = V_{std}\ >\ 1600\ (mg)$$

Condition 4 and 5 are used to determine if the guns was moved in cooking direction.

$$cond\ 4\ = X_{average\_max}\ >\ Y_{average\_max}$$

$$cond\ 5\ = X_{average\_max}\ >\ Z_{average\_max}$$

Condition 6 and 7 are used to include the information of the level of excitation at each axis at the moment of action.

$$cond\ 6\ = X_{abs\_average\_max}\ <\ Y_{abs\_average\_max}$$

$$cond\ 7\ = X_{abs\_average\_max}\ <\ Z_{abs\_average\_max}$$

To avoid misclassification the algorithm must detect the signal in two successive iterations; such that if the conditions are met the signal within the window is considered as a candidate of cooking the firearm and if in the next iteration the conditions were met again the signal within the window is classified as cooking action, furthermore the algorithm does not detect any signal until the detected signal leaves the detection window which at max can be 87 ms.

Charger Loading Detection

To detect charger loading action the following set of conditions is used.

Conditions Set 2

$$cond\ 1\ =\ V_{average\_max}\ >\ 4000\ (mg)$$

$$cond\ 2\ =\ V_{mean}\ >\ 1000\ (mg)$$

$$cond\ 3\ =\ V_{std}\ >\ 1300\ (mg)$$

$$cond\ 4\ =\ X_{average\_max}\ >\ Y_{average\_max}$$

$$cond\ 5\ =\ Z_{average\_max}\ >\ Y_{average\_max}$$

$$cond\ 6\ =\ Y_{abs\_average\_max}\ >\ X_{abs\_average\_max}$$

$$cond\ 7\ =\ Y_{abs\_average\_max}\ >\ Z_{abs\_average\_max}$$

Shot detection

To detect shot action the following set of conditions is used.

Conditions Set 3

$$cond\ 1 = V_{average\_max} > 8000\ (mg)$$

$$cond\ 2 = V_{mean} > 2000\ (mg)$$

$$cond\ 3 = V_{std} > 2700\ (mg)$$

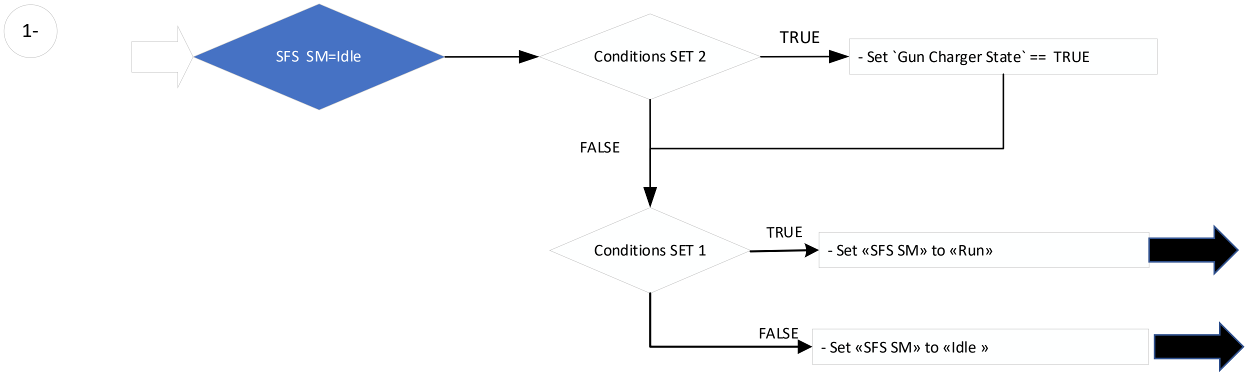
$$cond\ 4 = X_{average\_max} \geq Y_{average\_max}$$

$$cond\ 5 = X_{average\_max} \geq Z_{average\_max}$$

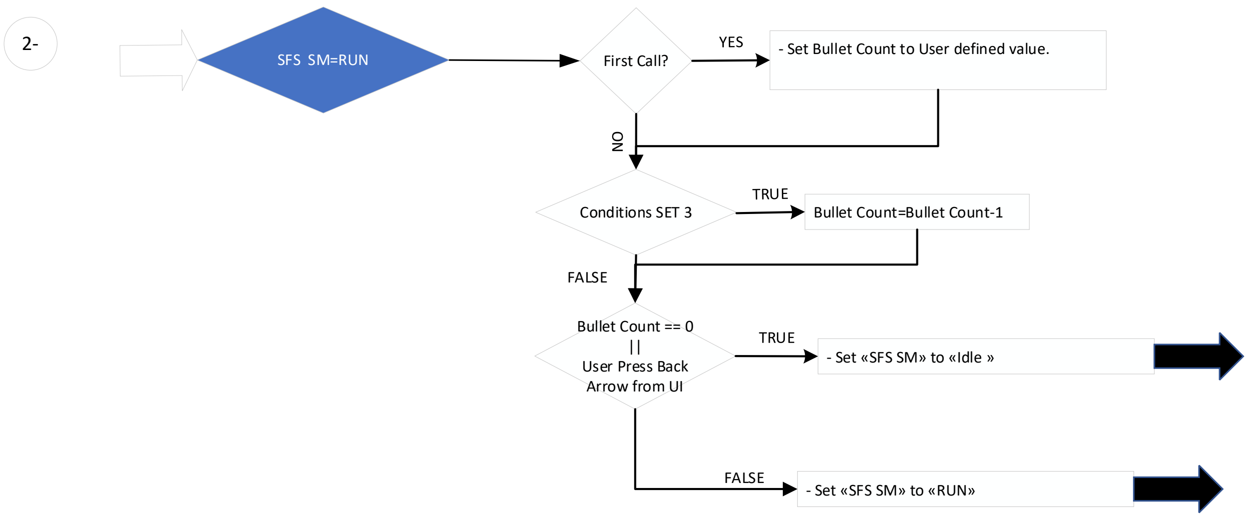
Recommended Flow Diagram

Above explained detection procedures can be checked continuously by software. However, to avoid miss or wrong detection especially between shot and cooking, following state machine structure is recommended. At the following structure, gun can be in two states : Idle(Safe) and Run(Loaded). State transition definitions are:

- To switch from idle to run state, cooking event must happen.
- To switch from run to idle state, gun must be run out of ammunition, or under the request of the user on smartphone.



1-
SFS SM=Idle
Conditions SET 2
TRUE
- Set `Gun Charger State` == TRUE
FALSE
Conditions SET 1
TRUE
- Set «SFS SM» to «Run»
FALSE
- Set «SFS SM» to «Idle »



2-
SFS SM=RUN
First Call?
YES
- Set Bullet Count to User defined value.
NO
Conditions SET 3
TRUE
Bullet Count=Bullet Count-1
FALSE
Bullet Count == 0
||
User Press Back
Arrow from UI
TRUE
- Set «SFS SM» to «Idle »
FALSE
- Set «SFS SM» to «RUN»