TrigCam: A smartwatch triggered wearable camera system for feeding habit monitoring

I. System description

A. Hardware setup

TrigCam system consists of a smartwatch paired with an android smartphone to trigger the recording of the videos at a raspberry pi based fisheye camera (TrigCam). TrigCam records the feeding videos from a first person perspective only when feeding gestures are detected at the smartwatch worn by a user.

Smartwatch triggers the phone and phone relays the triggers to the TrigCam to start 20 seconds of video recording at TrigCam for a trigger. Multiple consecutive triggers occuring in 20 seconds window are considered as a single Trigger to avoid backlogging of triggers.

Fig 1. TrigCam System

Bluetooth communication is used between the smartphone and TrigCam to relay the triggers received from the smartwatch paired with smartphone.

WiFi communciation- TrigCam is configured as WiFi hotspot to transfer the videos recorded at the TrigCam to phone memory every 5 minutes.

B. Software setup

i. App running at Smartwatch

Smartwatch app allows following three methods of triggering the TrigCam:

1. **AccelTriggering (Accelerometer)-** Roll and Pitch are calculated from the accelerometer values. A 3 state finite state machine is programmed to generate a trigger message whenever all three FSM states are covered.
2. **Orientation Triggering (9 axis) (Magnetometer, Gyroscope and Accelerometer)-** Uses accurate roll, pitch and azimuth information obtained from rotation matrix at the 3 state FSM to send trigger for video recording at the TrigCam.

3. **Orientation and Magnetic triggering- (6 axis) (Accelerometer and Magnetometer)**- Uses the roll, pitch and magnetic field to detect the feeding moments. Magnetic field generated by magnet holding the TrigCam to the users chest/shirt is used to detect the hand proximity at 3rd state of FSM of the smartwatch in addition to the roll and pitch information to generate trigger messages.

Fig 2. Smartwatch App

With the detection of feeding like moments the Bite/Trigger counter is incremented at the smartwatch and the same is updated at the app running at the mobile phone.

Note- Proximity sensor at the TrigCam is an optional feature that can be used to trigger the recording of the videos without the need of smart watch

ii . App running at Mobile phone

App running on the mobile phone runs a service to receive triggers from smartwatch and relay it to TrigCam. It also sets the time of the TrigCam to keep the time of the smartwatch, mobile phone and TrigCam synchronized.

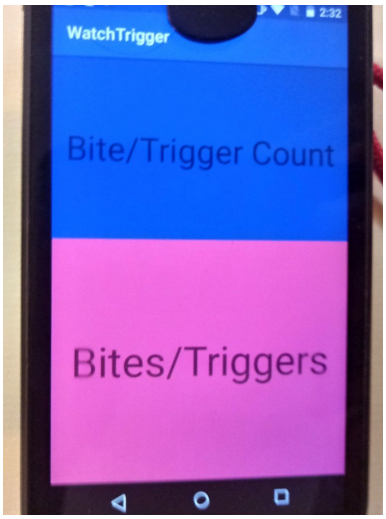

Fig 3. SmartPhone App

iii. Scripts running at TrigCam

1. **Bluetooth Server script-** To receive triggers from phone app to raspberry pi over Bluetooth
2. **Proximity Sensing script-** To trigger recording of the video based on Proximity of the hand (Optional).
3. **Camera record script-** To record 20 seconds of video every time a trigger is received.
4. **Video conversion script-** to convert videos from H264 to mp4 mobile readable format.
5. **Script to push video from the TrigCam to Mobile phone** -Sync the videos recorded with the phone over WiFi every 5 minutes.

Fig 4. TriCam assisted with a magnet

A magnet holds the TrigCam to the chest of the user and also aids in magnetic sensing during the Orientation and magnetic sensing Triggering.

II. TrigCam Testing description

A. Testing setup:

Three kinds of smartwatch triggers were tested on a subject for a week from 2-20-2018 to 2-26-2018 for 4-5 hours each day from about 10 am to 2 pm. During the testing the smartwatch and the TrigCam was worn by the subject. Mobile phone around the neck was also worn by the subject to record continuously video for the ground truth.

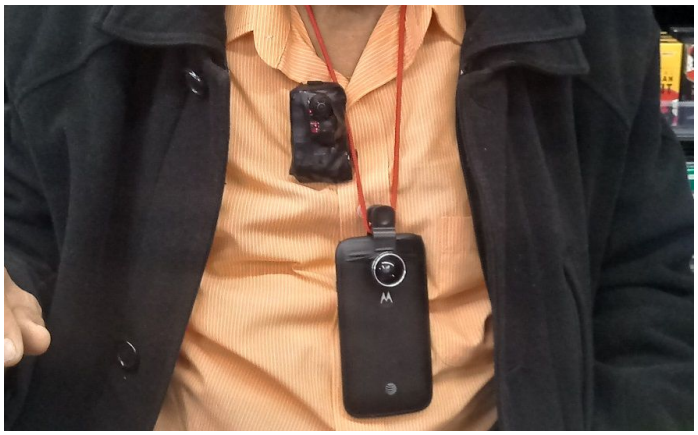

Fig 5. TrigCam testing setup

Tigger timestamps for each kind of trigger are dumped at the smartwatch and mobile phone and tabulated at the excel sheet. Video recorded by the TrigCam are timestamped.

B. Triggering Testing Results:

Following table shows the type of Triggering tested (1st column), total number of hours tested 2nd column), total number of triggers generated (3rd Column) and Triggers/hours (4th column) for each type of triggering. Number of videos recorded and the total hours of video recorded at the TrigCam are tabulated in the 5th and 6th column.

Table1. TrigCam Triggering summary and % Video RecordingTime Saved

Smart Watch Sensor	Total Number of hours tested	Number of Triggers Generated at Smartwatch	Triggers/hour	Number of Videos (20 seconds) recorded at Raspberry Pi	Total Video Record Time	%Video recording time at TrigCam	%Video recording time saved at TrigCam
Orientation Triggering	**7.72hrs**	**500**	**64.76**	**376**	**2.08hrs**	**27**	**73**
Orientation and Magnetic Triggering	**15.33hrs**	**956**	**62.36**	**509**	**2.82hrs**	**18.4**	**81.6**
Accelerometer Triggering	**3.83hrs**	**383**	**100**	**223**	**1.23hrs**	**32.2**	**67.8**

Note- Above table shows the aggregate results over the week, result for each day are presented at the excel sheet (refer Appendix).

% video recording time and % video recording time saved is tabulated in the 7th and 8th column.

%Video recording time at TrigCam= Total video record time at TrigCam/Total no. of hours TrigCam was tested

%Video recording time saved= 1-%Video recording time

Example:

%Video recording time saved (for Orientation Triggering)=1-(2.08/7.72)=73

Note:

- *Orientation and Magnetic sensing generated less number of triggers / hour and is more efficient as it takes magnetic proximity of the hand into consideration for detecting feeding gestures, thus reducing false positive due to raising of the hand away from chest.*
- *Orientation and Magnetic sensing showed highest amount of video recording time saved followed by Orientation triggering and Accel triggering.*

C. Power Consumption Testing Results

i. TrigCam power consumption

TrigCam power consumption and number of hours lasting (Theoretical vs Field Test)

Power consumption by the TrigCam was tested using a USB volt and ampere meter. 110mA is consumed during the idle periods (**when camera was OFF)** at the TrigCam whereas 310mA is consumed when **camera was ON**.

Fig. 6 Current consumption when Camera OFF (110mA) vs Current consumption when Camera ON (310mA)

Theoretical:

% Current consumption reduced when Camera is OFF w.r.t Camera is ON = (Current consumption when Camera ON- Current consumption when camera OFF)/Current consumption when camera is ON.

=>(310-110)/310=64.51

Note- 64.51 % less current is consumed by the device when Camera is completely OFF.

Theoretical hours lasting before TrigCam is dead

Number of hours lasting= mA of battery/ curernt consumption in mA

Battery used by TrigCam 2500mAh
Theoretical hours lasting of TrigCam when camera is always OFF=2500/110=22hrs
Theoretical hours lasting of TrigCam When Camera is always ON=2500/310=8hrs

Field Testing Results:

For various triggering methods the camera is switched ON for particular % of time so the % Energy saving is calculated as follows:

% Energy saving=%Max power that can be saved when Camera is always OFF at TrigCam X %Video recording time saved

Example:
%Energy saving(Orientation Triggering)=64.51X73/100=47.09

Table2. %Energy saving and number of hours lasted by TrigCam

Smart Watch Sensor	%Max power that can be saved when Camera is always OFF at TrigCam	%Video recording time saved	%Energy saving	Approx. number of hours observed before RaspberryPi is dead
Orientation Triggering	**64.51**	**73**	**47.09**	**7hrs**
Orientation and Magnetic Triggering	**64.51**	**81.6**	**52.64**	**9hrs**
Accelerometer Triggering	**64.51**	**67.8**	**43.73**	**8hrs**

Note: *Hours lasted by TrigCam during Field Testing is less compared to theoretical results due to various other losses and current consumption variabilities.*

ii. Smartwatch power consumption

Orientation sensing uses 9 axis IMU and involves sensor fusion to generate orientation values, hence consumes highest power compared to other triggering methods. For Orientation and Magnetic sensing only on 6 axis IMU were used leading a lower current consumption at the cost of missing out azimuth parameter. Accel sensing consumes least amount of current but is less reliable in triggering.

SmartWatch power consumption and approx. hours of endurance observed for various triggering methods are tabulated below:

Table3. SmartWatch power consumption and approx. number hours lasted before dead:

Smart Watch Sensor	Number of Sensor used	Current consumption at SmartWatch	Approx. Number of hours before smartwatch is dead
Orientation Triggering(9 axis)	**3(Accel, Gyroscope, Magnetometer)**	**0.4+5.9mA**	**6hrs**
Orientation and Magnetic Triggering(6 axis)	**2 (Accel, Magnetometer)**	**0.4mA+5mA**	**9hrs**
Accelerometer Triggering(3 axis)	**1(Accelerometer)**	**0.4mA**	**10hrs**

Note: In the design Orientation or Magnetic sensors are registered only when initial accelerometer triggering is detected at the smartwatch to further reduce the power consumption. If no accelerometer based triggering is observed for more than 20 seconds high level sensors are deregistered.

III. CONCLUSION:

Wearable systems are highly energy constrained devices. Reducing power consumption of wearable systems is an important aspect of any design. Camera forms a major power consuming component of a wearable system that is used in recording of videos during feeding gesture monitoring. Triggering of camera to record videos only during the feeding periods can save considerable amount of power. The proposed smartwatch triggered wearable camera systems called TrigCam has shown about 52% of energy saving for (6 axis) Orientation-magnetic triggering followed by 47 % and 43% of energy saving for (9 axis) Orientation and Accelerometer based triggering techniques over the always ON camera system.

Appendix:

Link to the excel sheet used for the testing:

https://docs.google.com/spreadsheets/d/1rhHm5edQgq9H4MNf9UuojpY9YJT3D4-q2xhZITTGVYs/edit?usp=sharing

Link to the Trigger timestamps were saved at the smartwatch and phone for each type:

https://drive.google.com/drive/folders/10hjr1oxbkRaLPhuxycpNjwBo_UhgFRzg?usp=sharing

Link to the Videos recorded by raspberry pi camera system pushed to phone peer to peer in live for each triggering:

https://drive.google.com/drive/folders/1E71oj9Yd2azMJRI1JE0RKdxtJ_A1zhNF?usp=sharing

Link to the videos recorded by the phone for the ground truth:

https://drive.google.com/drive/folders/1Z3DCQuwGeILuQxUSrvnTkfV9J1m6I31I?usp=sharing