DEPARTMENT OF COMPUTER SCIENCE

Automatically Correcting for a Time Drift in Accelerometers using RGBD C

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Declaration

This dissertation is submitted to the University of Bristol in accordance with the requirements of the degree of BSc in the Faculty of Engineering. It has not been submitted for any other degree or diploma of any examining body. Except where specifically acknowledged, it is all the work of the Author.

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Abstract

Obesity, depression, stroke, falls, cardiovascular and musculoskeletal disease are some of the biggest health issues and fastest-rising categories of healthcare costs in the UK. The associated expenditure is widely regarded as unsustainable and the impact on quality of life is felt by millions of people in the UK each day. With a rapidly ageing population - could technology be the answer to some of these problems?

SPHERE (a Sensor Platform for HEalthcare in a Residential Environment) is developing a number of different sensors that will combine to build a picture of how we live in our homes. This information can then be used to spot issues that might indicate a medical or well-being problem.

The technology could help by:

- Predicting falls and detecting strokes so that help may be summoned.
- Analysing eating behaviour - including whether people are taking prescribed medication.
- Detecting periods of depression or anxiety.

[1]

Within the SPHERE research group, one of the sensors being developed is a wearable accelerometer. This accelerometer induces a drift between the true time and the local time on the device large enough that the wearable needs to be re-synchronised for every use.

This document looks to consider video data from RGBD cameras around the house, which provides data on where the person is, together with the acceleration data from the wearable sensor. With this data it should be possible to design an algorithm which automatically corrects the time drift so that the accelerometer and the video remain synchronised.

This project has been broken down in the following steps:

1. Consider different types of temporal distortions which could take place on a device such as the one in question.
2. Implement a program which generates synthetic data and can apply any combination of the different types of temporal distortion.
3. Devise a method to compensate for the different temporal distortions.
4. Given a synchronised set of data from the accelerometer and the cameras, introduce artificial drifts between data sets and assess how well the method work.
5. Apply this method to real drifted data which has already been collected in the SPHERE house in three locations; hallway, living room and kitchen.

Implicit to all of these steps was a large amount of data formatting and visualisation.

Supporting Technologies

- Python for implementation.
- SciPy: Numpy, Matplotlib.... for help.

Notation and Acronyms

SPHERE	:	a Sensor Platform for HEalth in a Residential Environment
RGB-D Camera	:	ASUS Xtion PRO cameras which can track colour as well as depth.
Accelerometer	:	A three axis accelerometer on the dominant wrist, attached using a strap
Temporal Distortion	:	A discrepancy in the timestamp of the data
No Distortion	:	No discrepancy
Constant Distortion	:	Clock constantly offset from the ground truth clock
Linear Distortion	:	Clock slower or faster than the ground truth clock
Periodic Distortion	:	Clock sometimes is faster, sometimes is slower than the ground truth clock according to a s
Triangular Distortion	:	Clock sometimes is faster, sometimes is slower than the ground truth clock according to a t

Acknowledgements

Chapter 1

Contextual Background

Obesity, depression, stroke, falls, cardiovascular and musculoskeletal disease are some of the biggest health issues and fastest-rising categories of healthcare costs in the UK. The associated expenditure is widely regarded as unsustainable and the impact on quality of life is felt by millions of people in the UK each day. With a rapidly ageing population - could technology be the answer to some of these problems?

SPHERE (a Sensor Platform for HEalthcare in a Residential Environment), a partnership between University of Bristol, University of Reading and University of Southampton, is developing a number of different sensors that will combine to build a picture of how we live in our homes. This information can then be used to spot issues that might indicate a medical or well-being problem.

The technology could help by:

- Predicting falls and detecting strokes so that help may be summoned.
- Analysing eating behaviour - including whether people are taking prescribed medication.
- Detecting periods of depression or anxiety.

[1]

SPHERE will work with clinicians, engineers, designers and social care professionals as well as members of the public to develop these sensor technologies, making sure that the technology is acceptable in people's homes and solves real healthcare problems in a cost effective way. The SPHERE project also aims to generate knowledge that will change clinical practice, achieved by focusing on real-world technologies that can be shown working in a large number of local homes.

Within the SPHERE research group, one of the sensors being developed is a wearable accelerometer. It was decided that an accelerometer would be useful for monitoring health because... Currently, this accelerometer induces a drift between the true time and the local time on the device which is large enough that the wearable needs to be re-synchronised after every 20 minute use which is clearly not ideal. This document looks to consider video data from the RGB-D cameras around the house, which provide data on where the person is, together with the acceleration data from the wearable accelerometer. With this data it should be possible to design an algorithm which automatically corrects for the time drift so that the accelerometer and the video data remain synchronised.

1.0.1 Sensors and the Smart Home

Currently all sensors in the home are synchronised with NTP (Network Time Protocol) however the procedure that is currently in place is infeasible for real deployments because...

Accelerometers

Participants wear a sensor equipped with a tri-axial accelerometer on the dominant wrist, attached using a strap. The sensor wirelessly transmits data using the BLE (Bluetooth Low Energy) standard to several receivers positioned within the house. The outputs of these sensors are a continuous numerical stream of the accelerometer readings in units of g. Accompanying the accelerometer readings are the RSSI (Received Signal Strength Indications) that were recorded by each access point. The accelerometers record data at 20Hz, and the accelerometer readings range is 8g. RSSI values are also recorded at 20 Hz, and values are no lower than -110 dBm.

Due to the nature of the sensing platform, there may be missing packets from the data.

RGB-D Cameras

Video recordings are taken using ASUS Xtion PRO RGB-D cameras. Automatic detection of humans is performed using the OpenNI library, and false positive detections were manually removed by the organizers by visual inspection. In order to preserve the anonymity of the participants the raw video data are not shared. Instead, the coordinates of the 2D bounding box, 2D centre of mass, 3D bounding box and 3D centre of mass are provided. The units of 2D coordinates are in pixels (i.e. number of pixels down and right from the upper left hand corner) from an image of size 640480 pixels. The coordinate system of the 3D data is axis aligned with the 2D bounding box, with a supplementary dimension that projects from the central position of the video frames. The first two dimensions specify the vertical and horizontal displacement of a point from the central vector (in millimetres), and the final dimension specifies the projection of the object along the central vector (again, in millimetres).

RGB-D cameras are located in the living room, hallway, and the kitchen. No cameras are located elsewhere in the residence.

The current solution for avoiding this time drift affect the SPHERE group is to synchronize the sensor every X minutes?

This algorithm could more generally be used to synchronize two 1-dimensional signals such as voice recordings.

If the algorithm as a result of this project is able to correct for the drift of the SPHERE data, it will allow for advancements in the SPHERE project such as:

1. Detecting strokes????

Challenges involved in this project are:

1. NTP is infeasible because. . .
2. Dont know the current time drifts.

The high level objective of this project is to create an algorithm which can synchronize a 1-dimensional signal A with a ground truth signal B given that signal A has been affected by one of the following temporal distortions:

- No Distortion
- Constant offset
- Linear Distortion
- Periodic Distortion
- Triangular Distortion

This project could be broken down in the following steps:

1. Consider different types of temporal distortions which could take place on a device such as this one.
2. Implement a program which generates synthetic data and can apply any combination of the different types of temporal distortion.
3. Devise a method to compensate for the different temporal distortions.

4. Given a synchronised set of data from the accelerometer and the cameras, introduce artificial drifts between data sets and assess how well the method works. This may reveal new information about the SPHERE data which could influence the future of the project.

Implicit to all of these steps is a fair amount of data formatting and visualisation. I used Python for the implementation with SciPy which is an open source library of scientific tools for Python.

Chapter 2

Technical Background

2.1 Initial solution ideas

In a centralized system the solution is trivial; the centralized server will dictate the system time. Cristian's algorithm and the Berkeley Algorithm are some solutions to the clock synchronization problem in a centralized server environment. In a distributed system the problem takes on more complexity because a global time is not easily known. The most used clock synchronization solution on the Internet is the Network Time Protocol (NTP) which is a layered client-server architecture based on UDP message passing. Lamport timestamps and vector clocks are concepts of the logical clocks in distributed systems.

Cristian's algorithm Cristian's algorithm relies on the existence of a time server. The time server maintains its clock by using a radio clock or other accurate time source, then all other computers in the system stay synchronized with it. A time client will maintain its clock by making a procedure call to the time server. Variations of this algorithm make more precise time calculations by factoring in network radio propagation time.

Berkeley algorithm The Berkeley algorithm is suitable for systems where a radio clock is not present, this system has no way of making sure of the actual time other than by maintaining a global average time as the global time. A time server will periodically fetch the time from all the time clients, average the results, and then report back to the clients the adjustment that needs be made to their local clocks to achieve the average. This algorithm highlights the fact that internal clocks may vary not only in the time they contain but also in the clock rate.

Often, any client whose clock differs by a value outside of a given tolerance is disregarded when averaging the results. This prevents the overall system time from being drastically skewed due to one erroneous clock.

Network Time Protocol Network Time Protocol a class of mutual network synchronization protocol that allows for use-selectable policy control in the design of the time synchronization and evidence model. NTP supports single inline and meshed operating models in which a clearly defined master source of time is used ones in which no penultimate master or reference clocks are needed.

In NTP service topologies based on peering, all clocks equally participate in the synchronization of the network by exchanging their timestamps using regular beacon packets. In addition NTP supports a unicast type time transfer which provides a higher level of security. NTP performance is tunable based on its application and environmental loading as well. NTP combines a number of algorithms to robustly select and compare clocks, together with a combination of linear and decision-based control loop feedback models that allows multiple time synchronization probes to be combined over long time periods to produce high quality timing and clock drift estimates. Because NTP allows arbitrary synchronization mesh topologies, and can withstand (up to a point) both the loss of connectivity to other nodes, and ̈falsetickers ̈that do not give consistent time, it is also robust against failure and misconfiguration of other nodes in the synchronization mesh.

NTP is highly robust, widely deployed throughout the Internet, and well tested over the years, and is generally regarded as the state of the art in distributed time synchronization protocols for unreliable networks. It can reduce synchronization offsets to times of the order of a few milliseconds over the public Internet, and to sub-millisecond levels over local area networks.

A simplified version of the NTP protocol, SNTP, can also be used as a pure single-shot stateless master-slave synchronization protocol, but lacks the sophisticated features of NTP, and thus has much lower performance and reliability levels.

Clock Sampling Mutual Network Synchronization CS-MNS is suitable for distributed and mobile applications. It has been shown to be scalable over mesh networks that include indirectly linked non-adjacent nodes, and compatible to IEEE 802.11 and similar standards. It can be accurate to the order of few microseconds, but requires direct physical wireless connectivity with negligible link delay (less than 1 microsecond) on links between adjacent nodes, limiting the distance between neighboring nodes to a few hundred meters.

Precision Time Protocol Precision Time Protocol (PTP) is a master/slave protocol for delivery of highly accurate time over local area networks

Synchronous Ethernet Synchronous Ethernet uses Ethernet in a synchronous manner such that when combined with synchronization protocols such as Precision Time Protocol in the case of the White Rabbit Project, sub-nanosecond synchronization accuracy may be achieved.

Reference broadcast synchronization The Reference Broadcast Synchronization (RBS) algorithm is often used in wireless networks and sensor networks. In this scheme, an initiator broadcasts a reference message to urge the receivers to adjust their clocks.

Reference Broadcast Infrastructure Synchronization The Reference Broadcast Infrastructure Synchronization (RBIS) protocol is a master/slave synchronization protocol based on the receiver/receiver synchronization paradigm, as RBS. It is specifically tailored to be used in IEEE 802.11 Wi-Fi networks configured in infrastructure mode (i.e., coordinated by an access point). The protocol does not require any modification to the access point.

Global Positioning System The Global Positioning System can also be used for clock synchronization. The accuracy of GPS time signals is 10 ns[7] and is second only to the atomic clocks upon which they are based.

Chapter 3

Project Execution

3.1 Data Generator

This section is about my data generator:

- Why is it necessary?
- What features does it have?
- Why does it have these features? (Linked to different temporal distortions)

3.2 Methods

This section will be about the methods I have found which solve the different types of temporal distortion.

- What are the methods?
- How well do the methods work?
- Do other temporal distortions affect the performance?
- What combination of distortions are amendanble?

Chapter 4

Critical Evaluation

4.1 SPHERE Data Tests

Evaluation of SPHERE tests here.

4.2 Results

Results here.

Chapter 5

Conclusion

Future work: Use these assessments as a means of rejecting false positive skeletons. Skeletons are the format in which the data comes from the cameras. It contains information on the location of the main joints of the person i.e. elbow, wrist, knee etc.

Bibliography

[1] SPHERE. Sphere website, 2016. [Accessed 2nd April 2016].