BIRD Summer Studentship 2022

BIRD, in collaboration with the University of Bath and local experts at the RNHRD, funded another successful summer student scholarship. BIRD funded £3,120 for the studentship which was hosted by the Department of Computer Science at the University of Bath.

Bath Institute for Rheumatic Diseases

This year, BIRD's 2022 summer student, Louis Godtfredsen, worked with lead supervisor, Dr Christopher Clarke, and co-supervisors, Dr Dario Cazzola & Dr Raj Sengupta, on the project 'Automating the BASMI Measurement Using Pose Tracking on a Smartphone'.

The aim of the summer placement is to provide educational and research opportunities and experience for an undergraduate student in the area of arthritis research, one of the key aims of BIRD. This year's studentship provided hands-on experience of data-based research to give Louis a taster of what a career in research would offer..

Q&A with BIRD's 2022 summer student, Louis Godtfredsen

Louis full scientific report can be found below.

In layman's terms, please outline the project?

"In this studentship two pose estimation libraries were used to calculate the BASMI on an android phone. The libraries were MLKit and MediaPipe, the results were that MLKit was on average more accurate than MediaPipe with the implemented methods with an average BASMI error of 0.83 whilst MediaPipe averaged 0.99. It can be concluded that, due to the significant error in both MLKit and MediaPipe, further development would be required for the pose estimation libraries to increase their accuracy and to improve how measurements are taken digitally by users. In short, "MediaPipe and MLKit show promise as Pose Estimation libraries to be used for automating measuring the BASMI, however, further development is necessary to increase the accuracy."

On a scale of one (low) to ten (high) how much has undertaking the studentship led him to consider doing further research/a career in research?

"The past two months have been played a pivotal role in my decision on whether I wish to pursue research as a career. I can gladly say that I believe that is where I am headed and in large part due to the BIRD Studentship, so much so that not only do I wish to pursue research but, interdisciplinary research in medicine and computer science. Throughout the studentship a variety of issues and challenges were confronted. Although at times occasionally stressful, they served as valuable learning experiences whether they were issues within code or issues of a more practical/medical nature relating to the BASMI, the process of trial and error was both frustrating and invigorating, but throughout it all, I felt I was pushing myself and learning. I believe that, is the addiction of research, to learn and to explore. I can proudly say I am addicted and would score the studentship a solid ten for the impact it has had on me and my future career decisions."

On a scale of one (low) to ten (high) how much would he recommend a Summer Studentship to others?

"I would most certainly recommend the studentship to my colleagues and fellow students in the computer science department, but only if they wish to be challenged and to push themselves both with regards to skills relating to research such as writing code, formulating experiments, and presenting results, and to skills relating to day-to-day life such as being pragmatic when problems occur, time management and being social with your colleagues. So, for the people who love to problem solve and be social, a strong 10."

Any Last comments/thoughts?

"I hope BIRD continues to explore the possibility of automating the BASMI as I do believe the means are there and there may even be an implementation which has not been tried yet that could yield better results. Recently a new motion capture method called OpenCap has been released by researchers at Stanford [2] with accuracy similar to that of MoCap (which can be used to calculate the BASMI) but requires only two iPhones to achieve wonderful results. I believe this software would be a potential solution for the goal of automating the BASMI with the use of mobile phones."

Scientific Report: Automating the BASMI Measurement Using Pose Tracking on a Smartphone, Louis Godtfredsen

Lead supervisor: **Dr Christopher Clarke,** Human-Computer Interaction, Computer Science
Co-Supervisors: **Dr Dario Cazzola**, Sport, Health & Exercise Science, Department for Health, **Dr Raj Sengupta**, Consultant Rheumatologist and Visiting Senior Lecturer in Dept of Pharmacy and Pharmacology

1. Introduction

Over the course of two months, I investigated the viability of Pose Estimation Software Libraries implemented on mobile phones for users/patients to calculate their BASMI. As with many computer science students, there may a slight degree of impostor syndrome with regards to "programming skills". This project has undoubtedly put such thoughts to rest. Throughout the studentship I could feel my confidence and skill in turning ideas on paper into code, designing software, finding solutions, and tailoring them for my own needs. The studentship not only taught me the importance of creating a system to follow but also the importance of flexibility required for when things do not work as expected. The following paragraphs are a summary of what my studentship and exploration taught me as well as the results of this exploration.

1.1 Ankylosing Spondylitis and BASMI

Ankylosing Spondylitis is a form of arthritis affecting the spine resulting in limited movement, pain, and stiffness for diagnosed patients. The Bath Ankylosing Spondylitis Metrology Index (BASMI) is an index used to diagnose and monitor the diseases progression. The index is calculated using a set of five measurements with the result being a value on a scale from zero to ten, with zero indicating a healthy and mobile spine and ten being a spine with severely limited mobility. Currently, a trained physiotherapist would take these measurements for patients to calculate the index. However, due to the limited availability of physiotherapists and consequently the ability to consistently take measurements, patients and clinicians may have to go long periods of time before being able to understand the current state and progression of their disease.

1.2 Pose Estimation Frameworks

Pose Estimation is the process of tracking humans in photos or videos without the help physical markers. This project utilised BlazePose which consists of 33 Landmarks (the joints, eyes, nose etc.), two open-source libraries using BlazePose were used, namely, MediaPipe and MLKit.

1.3 Aim

With the significant development of Pose Estimation Software over the past five years, the possibility for leveraging these techniques in healthcare has opened. Consequently, this project aims to investigate the possibility of utilising Pose Estimation Software (BlazePose) in a smartphone to calculate the BASMI and to assess the accuracy of these measurements.

2 Experiment Design

All five BASMI (Tragular to wall, Lumbar Side Flexion, Intermalleolar Distance, Cervical Rotation, and Lumbar Flexion Schoeber's Modified) measurements are taken both physically (used as ground truth) and digitally. For each digital measurement the researcher must take a series of photos of the participant in the appropriate poses from which the landmarks are calculated from and consequently the final measurements. In all cases the participants measurements were taken physically (following the standard BASMI Measuring guidelines) and would hold the position until all appropriate photos were taken. A series of calibration measurements were taken to be used as references (to convert from pixel coordinates to centimetres) before any further measurements and pictures were taken. The reference measurements were namely, the index to wrist length, the index to elbow length and the ankle to knee length. In all cases the regular distance formula was used to calculate the distances between coordinates and was also used to calculate the ratio used to convert from pixel length to centimetres. It should be noted that MediaPipe has two different coordinate systems when it comes to its pose solution. One provides normalised image coordinates (x and y values range from zero to one for image width and height respectively) and the other provides coordinates in centimetres with the origin being the centre of the hips of any detected individual (hence for this coordinate system no conversion was required from pixel length to centimetres).

2.1 Tragular to Wall

A total of two photos are required for the digital Tragular Measurement. One from the right side and one from the left. As shown in figure 1 for each side the participant would have to touch the wall behind them. The output of this measurement were the coordinates of the index finger, the wrist, the elbow, and the ear for both the left side and right side.

2.2 Lumbar Side Flexion Three photos were required for the Lumbar Side Flexion measurement. A neutral pose, left extension and a right extension as in figure 2. Similar to the Tragular measurement the index finger, wrist and elbow coordinates were calculated. The index finger extension coordinates were then compared to the index finger coordinates in the neutral position i.e. for the right extension photo, the right index coordinate was calculated and the distance between the right index coordinate in the neutral position and the extended position were found.

Figure 1 Tragular to Wall digital measurement

Figure 2 Lumbar Side Flexion with Pose Estimation

2.3 Intermalleolar Distance
A single photo was required (figure 3) for the intermalleolar distance. From this image the ankle and knee coordinates were calculated (the ankle to knee was used as the reference measurement).

2.4 Cervical Rotation
The exact same methodology used for the Lumbar Side Flexion was implemented for cervical. Except with the poses as shown in figure 3. However, the landmark coordinates were not required for this one as MLKit implements a rotation method in its Face Solution, MediaPipe does not do this and hence was not used to calculate the cervical rotation.

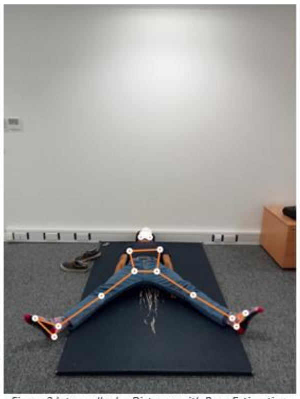

Figure 3 Intermalleolar Distance with Pose Estimation

Figure 4 Cervical Rotation with Pose Estimation

2.5 Lumbar Flexion Schoeber's Modified
Four photos were required for the Lumbar Flexion Schoeber's Modified measurement, two from the right side (figure 5) and two from the left. The manner in which this measurement was calculated differs entirely compared to the previous ones. The output coordinates were the hips and shoulders for both the neutral and extended poses. An assumption was used which is shown in figure 6. The angle created between the neutral shoulder, neutral hip and the extended shoulder was calculated (using the cosine rule) after which it was assumed hips were approximately the dimples of venus. As in the standard measurement the next point above the dimples is 10 centimetres up. From this the hypotenuse (x in figure 6) was calculated and the difference between x and 10 centimetres would be the final Lumbar. Flexion Schoeber's modified. Finally the average between the left and right measurements would be taken.

Figure 5 Lumbar Flexion Schoeber's Modified with Pose Estimation

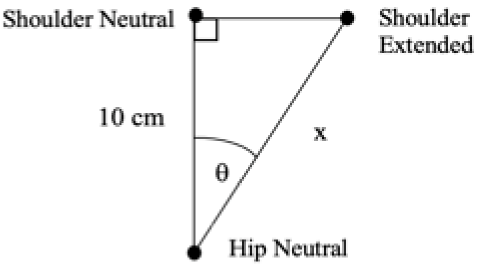

Figure 6 Lumbar Flexion Schoeber's Modified

3. Results

A total of eight participants were recruited for the experiment with 50% of participants being female and 50% males. The average age of participants was 22.3 years with a standard deviation of 4.7 years.

3.1 Tragular to Wall

As can be seen MediaPipe produces the least average error and standard deviation regardless of the reference measurement used compared to MLKit. This may be due to MediaPipe using a hand detection solution in tandem to the pose detection solution to better track the hand's position.

3.2 Lumbar Side Flexion

	LUMBAR SIDE FLEXION				
	Error in BASMI Index to Wrist MLKit	Error in BASMI index to Elbow MLKit	BASMI ERROR WORLD MediaPipe	BASMI ERROR Index to Wrist MediaPipe	BASMI ERROR Index to Elbow MediaPipe
AVERAGE:	0.50	0.63	0.86	0.71	0.86
STDEV:	0.71	0.48	1.12	0.70	1.12

Unlike with Tragular MLKit produces the least amount of error and standard deviation overall for the Lumbar Side Flexion measurement despite MediaPipe using the hand detection solution to better track the index finger coordinates.

3.3 Intermalleolar Distance

	INTERMALLEOLAR DISTANCE		
	Error in BASMI Ankle to Knee MLKit	Error in BASMI WORLD MediaPipe	Error in BASMI Ankle to Knee MediaPipe
AVERAGE:	1.25	0.57	1
STDEV:	0.97	0.73	1.31

MediaPipe using the world coordinate system produced significantly more accurate results compared to MLKit or using the ankle to knee measurement as reference. This is most likely due to the world coordinate system being able to compensate for the individual lying at an angle (due to the photo not being taken completely parallel to the participant), hence producing better results.

3.4 Cervical Rotation

	CERVICAL ROTATION
	Error in BASMI MLKit
AVERAGE:	0.63
STDEV:	0.70

MLKit's Face Detection Solution with the rotation function provides quite good results relative to the other measurements such as the intermalleolar distance and Tragular to wall.

3.5 Lumbar Flexion Schoeber's Modified

	LUMBAR SIDE FLEXION SCHOEBER'S MODIFIED		
	BASMI Error MLKit	BASMI ERROR WORLD	BASMI ERROR NORMALISED
AVERAGE:	4.88	5.43	3.38
STDEV:	1.27	1.59	1.73

As can be seen it is clear that the assumption used to calculate the Lumbar Flexion Schoeber's Modified introduces too large of an error for all coordinate systems (no reference measurement was required for MLKit or the normalised coordinate systems) even compared to previous errors found in the other measurements.

3.6 Overall Result and Average Error

	MLKit OVERALL BASMI ERROR	MediaPipe OVERALL BASMI ERROR
Average	0.83	0.99
STD	0.57	0.53

The table above shows the total average error for MLKit and MediaPipe over all coordinate systems/methods. Both show almost an average error of one however, it should be noted that this low error may be due to extreme errors (lumbar side flexion or tragular for example) in individual measurements cancelling each other out resulting in a perceived increased accuracy. A larger sample size would be required with a greater variety of BASMI scores for participants before any conclusion can be drawn as to which one is more accurate.

4. Conclusion

In conclusion, both MLKit and MediaPipe produced significant errors with the implemented methods undermining the viability of using them to automate the BASMI. However, due to the small sample size it should be noted that more tests would have to be done to conclude this entirely. There are a significant number of errors introduced throughout testing. From measuring reference lengths to picture quality and to the Pose Estimation Libraries themselves. Picture quality and measuring references are dependent on users but there may be other pose estimation libraries better suited for automating the BASMI. As stated BlazePose works on a skeletal framework and hence does not consider surrounding material/flesh which introduces error as physical measurements are not taken from the bone. Hence, a mesh-based pose framework such as DensePose [1] may offer a solution to this error, nevertheless it is computationally expensive and thus would require users sending data to a server to be processed rather than working locally on the phone.
For improving accuracy using the implemented frameworks a mix of both MediaPipe and MLKit could be done instead of using one exclusively. MLKit outperformed MediaPipe in Lumbar Side Flexion and Lumbar Flexion Schoeber's Modified but MediaPipe was significantly more accurate for the intermalleolar distance using the world coordinate system and calculating the tragular distance. Another improvement would be changing the way the photos/measurements are taken digitally. For the Lumbar Side Flexion, Lumbar Flexion Schoeber's Modified and Cervical Rotation a neutral position photo (as in the middle photo in figure 2) had to be taken to compare the extension photo with. This introduces more errors as users may not be taking the picture from the same distance or elevation. If instead a user would only have to take a single photo for each measurement (as in the tragular measurement) this would eliminate errors and may improve accuracy significantly. MLKit and MediaPipe, although powerful and incredibly useful, require further development to improve accuracy before they can be implemented for everyday users to calculate and monitor their own health. For the BASMI specifically, despite the errors, investigating different methods and modifying the ones shown in this report show promise for further reducing error which could lead to significant improvements potentially resulting in a relatively accurate and fully automated mobile BASMI measuring system.

Bibliography

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