Oli, Your Weight-Training Assistant

Karanbir S. Toor
University of Washington
1900 Commerce St, Tacoma,
WA 98402, USA
toork@uw.edu

Charlton M. Smith
University of Washington
1900 Commerce St, Tacoma,
WA 98402, USA
azoni@uw.edu

Ameet S. Toor
University of Washington
1900 Commerce St, Tacoma,
WA 98402, USA
ameet2r@uw.edu

Alexander G. Orozco
University of Washington
1900 Commerce St, Tacoma,
WA 98402, USA
ao1013@uw.edu

CHI'17 Extended Abstracts, May 06-11, 2017, Denver, CO, USA
ACM 978-1-4503-4656-6/17/05.
http://dx.doi.org/10.1145/3027063.3048429

Abstract
UPDATED—February 20, 2017. Weight-training has become a popular way of maintaining health and general wellbeing. However, many U.S. emergency departments have had an increase in injury incidences related to weight-training. We have designed an application, called Oli, which tracks a user's form and highlights injury causing movements. Oli assists users with weight-training by providing real-time feedback & analysis of lifts via utilization of frame by frame image processing. In this paper, we list our methods and the capabilities of our Kinect based system to process real time data and analyze form on particular weight-training movements.

Author Keywords
Tracking, Visual Analysis, Human-Computer Interaction, Weight-Training, Physical Fitness.

ACM Classification Keywords
I.4.8 [IMAGE PROCESSING AND COMPUTER VISION]: Scene Analysis; I.4.9 [IMAGE PROCESSING AND COMPUTER VISION]: Applications; H.5.2 [INFORMATION INTERFACES AND PRESENTATION]: User Interfaces

Introduction
Weight-training has become a popular way of maintaining health and general well being. However research has

shown an increase of over 48% in physical injuries caused due to weight-training. Over which 90% of the injuries have been attributed to the use of free-weights over weightlifting machines [12] in 2007 over 72 thousand injuries among 33 million participants, an increase in 2009 up to 86 thousand with a continual annual rise up to over 100 thousand in 2014, putting weight lifting within the top 10 sports related injuries [10]. Although free weights can be dangerous, they have shown to be more effective than their fixed weight counterparts in increasing balance and strength while reducing general pain [18]. Our Kinect based form tracking software, called Oli, aims to correct injury causing movements when using free weights, alongside a personal trainer or physical therapist, and helps generate useful metrics to track progress. Oli is designed to assist users with weight-training and provide real-time feedback & analysis of their lifts by utilizing underlying technology of image processing and frame by frame analysis.

Our research objective is to validate that using the Kinect for tracking and visualization, we can successfully analyze real time data from the human body and use it to generate metrics and injury alerts. Oli does not have a direct competitor to compare with, which is why we have decided to have a panel of experts evaluate Oli. Experts in human kinetics, like physical therapists and personal trainers, have extensive experience in understanding the precise movements of the human body and are able to tell when a genuine injury causing movement has occurred. Experts in the physical sciences such as physicists will help vet our metric calculations such as our force generation equation. Normally, an expensive force generating device is attached to the free weight or user to generate data. Oli aims to do this visually when set up with the weight being lifted and the user's weight.

By using the Microsoft Kinect we have the means to calculate the necessary metrics to develop a holistic platform to help aid in form correction, resulting in a reduced risk of injury. Our team explores the data produced by the Kinect by analyzing the tracked movement patterns to determine if the user is performing the selected lift correctly. Oli also analyzes metrics of the joints including angle, positioning, and force. Oli retains pertinent statistics as the user exercises and displays the resulting data at the end of the session. We aim to help users correct injury causing movements in the early stages of weight-training and help experienced weightlifters refine their lifts to maintain a healthy lifestyle.

Literature Survey

The Kinect has many games that are great for rehabilitation and for fitness [14, 20]. A few of the games that are available are: Your Shape: Fitness Evolved, Kinect Sports Season 2, and Nike+ Kinect Training. One rehabilitation program that is available is the JINTRONIX rehabilitation program [11]. Some of the games like Nike+ Kinect Training, and Your Shape: Fitness Evolved, are a great way to replace cardio exercises [8]. Others give stats on how the user is progressing in their movements to help clinicians with documentation, like JINTRONIX [11].

While these programs and games are a good way to get people moving, some of their disadvantages are that they lack the ability to detect physical injuries caused during fitness activities, they lack the ability to track human body form during physical activity, resulting in high rates of musculoskeletal injury and, they lack the ability to generate useful metrics which serious weightlifters need, like the calculation of a user's one rep max [1, 9].

Another previous work that has been done is called MotionMA, this system used the Microsoft Kinect to train the

system on how to correctly do the lift and to monitor to see if the user did the lift correctly [19]. Although this system is great to watch incorrect movements, the hardware that is used is a Kinect V1, which is older and not as refined as the Kinect V2.

To correct these disadvantages and hardware issues we proposed and built a Kinect V2 based tracking software called Oli, with the aim to provide users a weight-training platform which has the ability to monitor, track and suggest correct form and body posture to necessitate proper weight-training techniques, with the objective of reducing the chances of sustaining any physical injury.

Research Objective

1. Oli is a Kinect based weight-training software that allow users to train in weightlifting techniques without the need of any physical tracking devices.

2. Oli is designed to track users form and body posture, while providing real-time feedback, alert and analysis of correct weight-training technique, with the aim to increase stability and reduce injury rates.

3. All of Oli's data is recorded so it may be accessed by a physical therapist, trainer or the user to facilitate a healthy lifestyle.

Implementation Details

It is important to make an accurate assessment of the presence, severity of all injury causing movements, and risks associated to the user. Physical activity is multidimensional and is a complex behavior to measure. We plan to implement Oli which will track various components of an intended exercise, duration, frequency through rep counting and intensity by calculating force.

Based on a related study on energy expenditure using the Kinect V2, the system accurately tracks angles and joint positioning [15]. To properly implement our user and expert study, we keep human to system interactions simple and easy to understand. We will be implementing a user friendly design to mask the complexity of our underlying algorithms and features. The bulk of our calculations are done by measuring current joint positioning, and tracking different angles. This is done by using the cartesian plane (x,y,z) with Euler angles and timestamps for each frame. We are also able to estimate force to produce a one rep max calculation.

Oli will utilize the built in Microsoft SDK to initialize the framework of our platform. Oli tracks 25 different joints which are used to produce the angles we need from the dot product of two joint vectors. Oli generates a visual skeleton overlay of the joints for our users to help them clearly track form. Figure 1 below gives you a visual perspective of the user interacting with Oli. Notice the areas around the skeleton are populated with three different color coded messages: instructional messages, helpful tips, and warning messages. These messages appear to the user in real time when the system detects an anomaly or at specific parts of the movement provide helpful feedback to continue the lift. This is to help correct form issues that may be difficult to detect during lifts and provide the user with feedback as these issues appear.

We are currently tracking the squat, overhead press, deadlift, clean, jerk and bench press exercises. Each exercise is divided into various stages and these stages have their own injury detection calculations that are run for each frame the Kinect captures. Injury causing motions are detected by looking at the angles of major joints such as the shoulders and knees along with their relative locations in the coordinate space. The angles are calculated by taking the dot

Figure 1: Post workout the user can review their lift. The entire workout is saved so the user can review any lifting errors they may have performed.

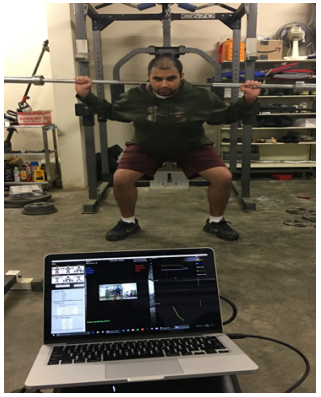

Figure 2: Our system warns a user that the bar is no longer level during a squat exercise. This error is stored so that a user may review their lift at their convenience. Our system aims to be implemented alongside a screen so the user may see the feedback that is being processed real-time and correct their form.

product of the joint vectors in question. Thresholds are set based on lift being performed.

Oli has a multitude of features that the user may choose based upon their specific needs. One of our highlighted features of Oli is our frame by frame analysis (Figure 2), and user reports. We want the user to have access to past workouts to help assess progress, as well as locate problem areas that may have been missed. The interactive model will save the data, and be analyzed in real time, providing instant feedback (see Figure 3).

Another feature of Oli is the ability to calculate the force generated by measuring the displacement of the weight being lifted. The user inputs the weight they are lifting and Oli outputs the force onto a graph as the user performs the lift (see blue highlighted box in Figure 2). After each exercise, Oli calculates the user's one-repetition maximum using a combination of the McGlothin and Lombardi formulas.

We are tracking the following injury causing movements:

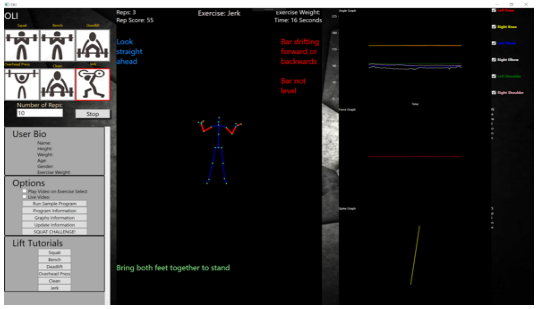

Figure 3: Here we show an error during the jerk exercise.

- Adequate squat depth [5, 6]
- Knees bending horizontally inward, outward or too far forward sagittally for the deadlift, squat, clean and jerk exercises [4, 7, 17]
- Sagittal Bar position relative to the shoulders for shoulder stability during the jerk and overhead press exercises [2, 3, 7]
- Vertical bar position relative to the shoulders during the bench press exercise [13]
- Sagittal Bar position relative to the knees during the deadlift and initial phase of the clean exercises to reduce excessive back strain [16]
- Angles of major joints of the body such as: knees, shoulders and elbows

System Evaluation

Two sets of evaluation studies will be conducted on Oli:- Expert Evaluation and User Study. Certified physical trainers will be recruited as experts to statistically and quantitatively

evaluate the software. A series of studies will be conducted comparing expert reviews to that of Oli's and measuring the number of type 1 and type 2 errors. An error occurs where an expert says the user made an incorrect movement while lifting and Oli doesn't catch it, likewise if Oli thinks there is an incorrect movement and all experts agree otherwise, this would also be considered as an error. The goal is to measure the accuracy of Oli's real-time error detection system. At the end of the study a heuristic evaluation will be conducted by the experts, based on visibility, learnability, design and consistency of the software system.

A user study will be conducted by recruiting participants from a local gym who are currently undergoing weight-training. The user study will be conducted on an one-on-one basis, in a dedicated setup. We will be isolating the participants to avoid noise and tracking interferences with the Kinect. During the testing session, participants will be asked to fill out a pre- and post-experiment questionnaire. The pre-experiment questionnaire will focus on demographic information of the participants along with their their workout history, lifestyle and weight lifting experience. Whereas, the post-experiment questionnaire will focus on the usability of the software. During the testing session, the participants will be asked to perform 10 reps of 6 different exercises, based on the guidance tutorial videos. The interaction between the participant and the system will be recorded and analyzed by the experts along with their tracking data charts generated during each interaction.

Conclusion, Discussion and Contribution to HCI

Oli aims to keep users healthy and prevent injury using it's injury detection software. We are starting conservatively with injury detection as we test the program through user studies as our bodies come in many shapes and sizes, and this has the potential to affect our calculations. As we gain user data we will refine the thresholds of injury detection and modify injury detection using feedback from our expert study.

Hospital injury rates related to weight-training have risen and there is a need for a low-cost solution to reduce the number of injuries. Our goal is to deliver a holistic platform to support active and healthy lifestyles over the long term. Gyms and fitness centers offer many services to help members improve form and fitness. The most popular service being a personal trainer. However, this service may be too expensive or overkill for a single lift or a beginner simply trying to understand the lift. Oli aims to fill this need along with the need to provide personal trainers with a tool that can help their clients better understand the areas they need to focus on. Using frame by frame analysis, generated metrics, and the skeleton joint overlay clients of our system can pinpoint areas of strength and weakness to benefit the most from their workouts while minimizing the risk of injury. Clients who wish to repeatedly use Oli will notice that Oli measures progress as well. Our goal is that Oli will motivate users to continue lifting by showing users how they are progressing over time all while keeping them injury free.

Acknowledgements

This was the first time writing an extended abstract for all four of us students and we could not have accomplished this feat without the aid of our mentor, Dr. Raghavi Sakpal. Thank you for your continued support throughout holidays, long office hours and commitment to our success.

References

[1] Majed A Alabbad and Qassim I Muaidi. 2016. Incidence and prevalence of weight lifting injuries An update. *Saudi Journal of Sports Medicine* 16, 1 (2016).

[2] Lee Boyce. n.d. Rookie Mistakes: The Overhead

Press. (n.d.). http://www.mensfitness.com/training/pro-tips/rookie-mistakes-overhead-press.

[3] Todd Bumgardner. 2015. How To Overhead Press: A Beginner's Guide. (2015). http://www.bodybuilding.com/fun/how-to-overhead-press-a-beginners-guide.html.

[4] Cyberpump. 2016. How To Squat: Proper Techniques For A Perfect Squat. (2016). http://www.bodybuilding.com/content/how-to-squat-proper-techniques-for-a-perfect-squat.html.

[5] Stephen A. Grabe and Carol J. Widule. 1988. Comparative Biomechanics of the Jerk in Olympic Weightlifting. *Research Quarterly for Exercise and Sport* 59, 1 (1988), 1–8. DOI:http://dx.doi.org/10.1080/02701367.1988.10605466

[6] H. Hartmann, K. Wirth, and M. Klusemann. 2013. Analysis of the Load on the Knee Joint and Vertebral Column with Changes in Squatting Depth and Weight Load. *Sports Med* 43 (2013), 993. DOI: http://dx.doi.org/10.1007/s40279-013-0073-6

[7] Jeremy Hoefs. 2016. How to Do the Clean and Jerk Exercise. (2016). http://www.livestrong.com/article/537116-how-to-do-clean-jerk-exercises/.

[8] Hayley Holmes, Jamie Wood, Sue Jenkins, Peta Winship, Dianne Lunt, Susan Bostock, and Kylie Hill. 2013. Xbox Kinect Represents High Intensity Exercise for Adults with Cystic Fibrosis. *Journal of Cystic Fibrosis* 12, 6 (2013), 604–608.

[9] Jennifer M. Hootman, Carol A. Macera, Barbara E. Ainsworth, Malissa Martin, Cheryl L. Addy, and Steven N. Blair. 2001. Association among Physical Activity Level, Cardiorespiratory Fitness, and Risk of Musculoskeletal Injury. *American Journal of Epidemiology* 154, 3 (2001), 251–258.

[10] Insurance information Institute. 2014. Sports Injuries By Number of Injuries, 2014. (2014). http://www.iii.org/table-archive/21160.

[11] Jintronix. 2016. Kinect Rehabilitation Software. (2016). http://www.jintronix.com.

[12] Zachary Y. Kerr, Christy L. Collins, and R. Dawn Comstock. 2010. Epidemiology of weight training-related injuries presenting to United States emergency departments, 1990 to 2007. *The American Journal of Sports Medicine* 38, 4 (2010), 765–771.

[13] Alec Khlebopros. 2015. How to Avoid Pain and Injury When Bench Pressing. (2015). http://charlottechironc.com/avoid-pain-injury-bench-pressing/.

[14] Christine Lachance. 2016. How to Use Your Xbox to Get in Shape. (2016).

[15] David Nathan, Du Q. Huynh, Jonas Rubenson, and Michael Rosenberg. 2015. Estimating Physical Activity Energy Expenditure with the Kinect Sensor in an Exergaming Environment. (2015).

[16] Layne Norton. 2016. How To Deadlift: Layne Norton's Complete Guide. (2016). http://www.bodybuilding.com/fun/how-to-deadlift-layne-nortons-complete-guide.html.

[17] Michael S. Palmieri. 2013. Meet The Clean: Your First Step Toward Olympic Lifting. (2013). http://www.bodybuilding.com/fun/meet-the-clean-your-first-step-toward-olympic-lifting.html.

[18] Keith C. Spennewyn. 2008. Strength outcomes in fixed versus free-form resistance equipment. *The Journal of Strength and Conditioning Research* 22, 1 (2008), 75–81.

[19] Eduardo Velloso, Andreas Bulling, and Hans Gellersen. 2013. MotionMA motion modelling and analysis by demonstration. (2013).

[20] Wenbing Zhao, Hai Feng, Roanna Lun, Deborah D. Espy, and M. Ann Reinthal. 2014. A Kinect-based Rehabilitation Exercise Monitoring and Guidance System. (2014).