corpusLabe - a gamified goniometer for clinical evaluation

Team Name

Brighter Eyes Lynxes

The Iberian lynx (Lynx pardinus) is a wild cat species endemic to the Iberian Peninsula in southwestern Europe that reached the verge of extinction before conservation measures were implemented which included improving habitat, restocking of rabbits, translocating, re-introducing and monitoring Iberian lynxes. The name lynx derived from the Indo-European root leuk- ('light, brightness') in reference to the luminescence of its reflective eyes. [wikipedia]

Region

Europe+Russia+Australasia

Category

Health and Fitness

Problem Statement

Introduction

Notwithstanding continued multi-disciplinary research providing for survival rates to keep improving [1], the following reality prevails:

> *"Breast cancer is the most common incident cancer among women, is the leading cause of cancer deaths, and causes the most disability adjusted life-years (DALYs) lost around the world."* (Duggan, Dvaladze, Rositch, et al. 2020)

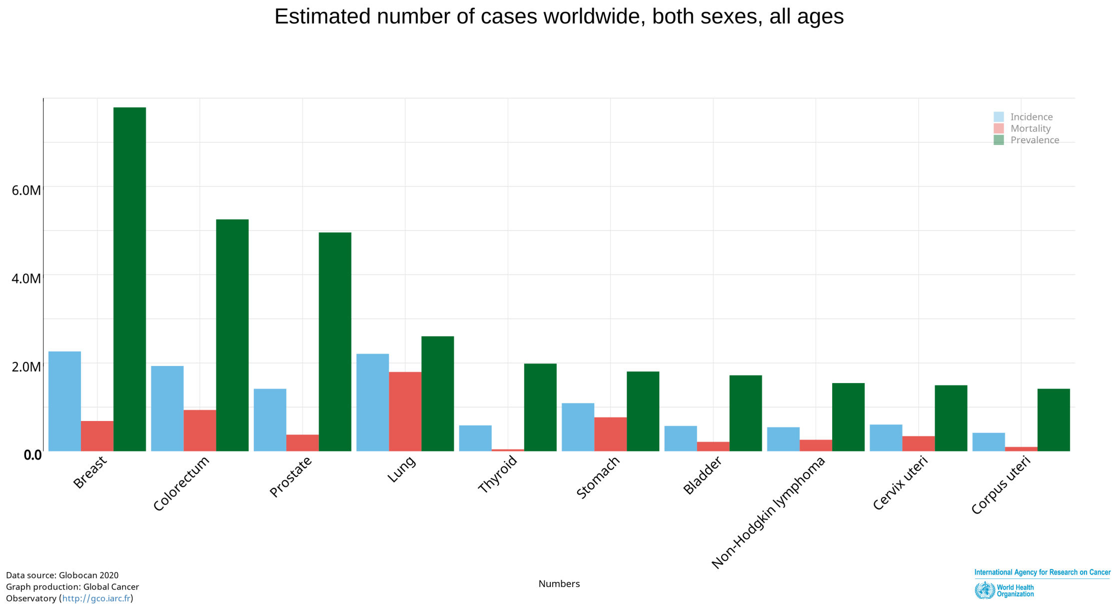
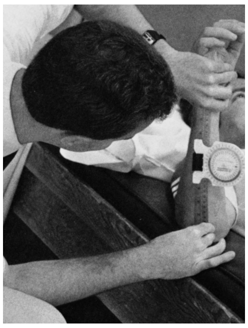


Figure 1: Worldwide incidence, mortality and prevalence of main cancer sites sorted by prevalence numbers according to the World Health Organization's International Agency for Research on Cancer's Global Cancer Observatory (`http://gco.iarc.fr`).

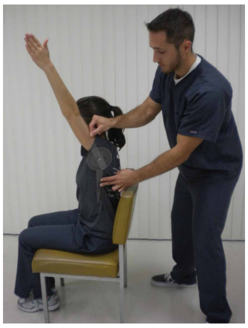
As breast cancer survivors (BCS) are living longer (Fig. 1), the adverse effects resulting from the cancer treatment are more frequent. Upper body morbidity (UBM) (e.g. decreased range of motion, muscle strength, pain and lymphedema) are among the most prevalent side effects [3].

Regarding lymphedema alone, it has been estimated that over 1 million BCS in the United States [4] may meet the criteria for breast cancer-related lymphedema (BCRL). Lymphedema is a swelling condition, resulting from lymphatic ablation commonly associated with breast cancer treatment (BCT). Women who have undergone BCT are at a risk of developing BCRL during their lifetimes, which impacts on different dimensions of a woman's quality of life [5]. Clinical assessment of the condition is usually performed by evaluating the difference in volume between the operated side and the other, or, against a pre-operative measurement [6]. Objective measurement techniques in use include bioimpedance spectroscopy, arm circumferences, water displacement or lymphoscintigraphy. However, it was shown that some patients develop symptoms of BCRL without objective changes in arm circumference, indicating that its incidence and impact may be underestimated [7].

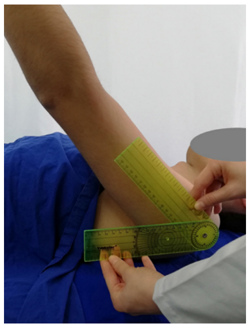
On the other hand, arm/shoulder mobility, usually assessed by goniometer-based measurements of flexion, is an objective measure of UBM that has been used in breast cancer rehabilitation, although its well established use covers much broader application scenarios (Fig. 2). More recently, several studies proposed the use of vision and inertial based sensing solutions for UBM assessment through the estimation of the reachable workspace based on hand and shoulder computed trajectories [8]–[12]. However, current systems of specific joint motions assessment still present limitations as general tools for robust and reliable UBM analysis with clinical relevance, namely, performance degradation of pose estimation for less constrained acquisition scenarios. In addition to the discussion related to the validity of the application of tools based on machine learning methods involving data collection, there is a recurring discussion on topics such as preservation of privacy, security and transparency, which, in the area of health care gains even more relevance [13]–[15].



(Andrews and Bohannon 1989)



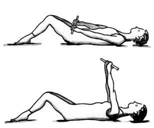
(Kolber, Fuller, Marshall, et al. 2011)



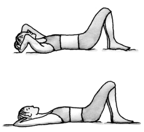
(Çubukçu, Yüzgeç, Zileli, et al. 2020)

Figure 2: Illustration of the use of a goniometer for the quantification of shoulder range of motion.

Besides UBM assessment itself, the proposed prospective surveillance model for BCS [18] highlights the importance of monitoring for functional and physical impairments commonly associated with BCT. Also highlighted by the prospective model is the need to adopt long-term follow-up strategies (Fig.3) supported by objective widely available assessment methods. In that sense, methods for clinical and at home use to eliminate biases and recall inaccuracies from self-reported data, as well as achieve early detection, promote risk-reduction and self-management procedures are still missing [19].

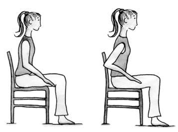


(Wand exercise)

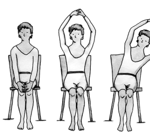


(Elbow winging)

(Shoulder blade stretch)

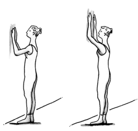


(Shoulder blade squeeze)



(Side bends)

(Chest wall stretch)



(Shoulder stretch)

Figure 3: Illustration of commonly recommend exercises for women after breast surgery as presented by the Oncology Section of the American Physical Therapy Association (`www.cancer.org`).

Objectives

The main objective of the proposed work is to explore the potential of edge spatial AI as part of an exercise monitoring tool aimed at collecting clinically relevant data. Considering the breast cancer treatment follow-up scenario as a study case, we propose to evaluate the OpenCV AI Kit (OAK-D) against the gold standard goniometer for the determination of the range of motion for shoulder flexion. A virtual goniometer using OAK-D is therefore to be implemented and evaluated. In that evaluation, for a given human pose estimation approach, the impact of the depth from deep neural inference and stereo depth camera pair estimation is to be studied in light of its ability to provide robust measures of range of motion. Furthermore, and adding both a postural analysis and a graphical user interface layers, a gamified virtual goniometer is to be developed and made available for future work. Following, an overview (Fig.4) of the main tasks is presented:

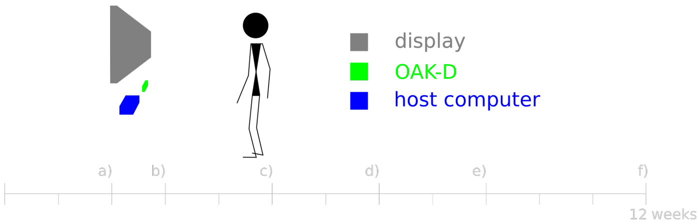


Figure 4: Representation of the proposed OAK-D system elements and planned 12 weeks timeline.

a) **OAK-D set-up** - Familiarization with OAK-D API and OpenVINO.

b) **Human pose estimation** - Having the goal to predict a body skeleton in space, OpenVINO Human Pose Estimation demo, OAK-D calibration data and alternative approaches to estimate depth (stereo and monocular based) are to be tested running and serve as a baseline for the problem of localization of human joints. In the context, the scenario of a single person being observed is to be considered, and the working range of depth and pose recovery explored in order to establish a reference relative placement of OAK-D and monitored human.

c) **Goniometer data test** - Implementation of a routine to enable a trained operator to trigger the acquisition of a list of human pose joint locations followed by the computation of the maximum shoulder flexion angle from recovered human pose (Fig. 5). Considering the possibility to use distinct approaches for depth estimation, a group of voluntary healthy subjects is to be used in order to compare measurements of shoulder flexion against a standard goniometer. The operator should verbally guide the voluntary subjects to perform equivalent poses for both the moments of registering the goniometer reading and while using the OAK-D system.

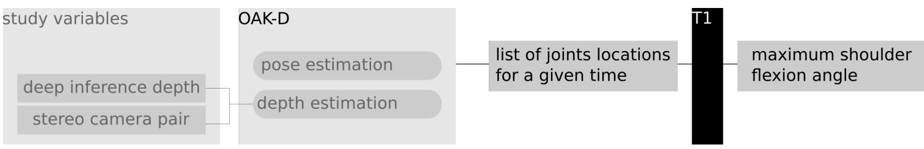


Figure 5: Outline of the proposed goniometer data experience considering the computation of the maximum shoulder flexion angle from a list of joints locations(T1).

d) **Postural analysis** - To provide to a given user a target pose which one must try to mimic, the task of matching human poses is to be implemented considering both the procrustes superimposition and the evaluation of shape differences in a given time window problems.

e) **Pose visualization** - Considering the pose output format resulting from the human pose estimation methodology to be used, a simple graphical user interface is to be implemented. Aiming at keeping the visual feedback as light and clean as possible it should be adopted a simple body joint projection of selected parts with the possibility to highlight specific body joints for specific situations, as well as the possibility of displaying sporadic textual messages.

f) **Gamified goniometer prototype** - Implementation of a prototype virtual goniometer to enable user's independent range of motion assessment (Fig. 6). Considering as test set of target poses of interest the shoulder stretch movement (Fig. 3) for both left and right arms, the prototype should provide visual feedback to guide the user to repeat each movement a given number of times. Additionally, the system should compare the user's current and target pose, and determine if a given interest pose was at least partially performed by the user. For each repetition, the user's closest pose to the target should be considered to estimate the maximum shoulder flexion angle. An intermediate score can be computed and presented to the user after the first pose execution, providing feedback for each repetition on whether the maximum shoulder flexion is changing in comparison to the previous execution of the movement.

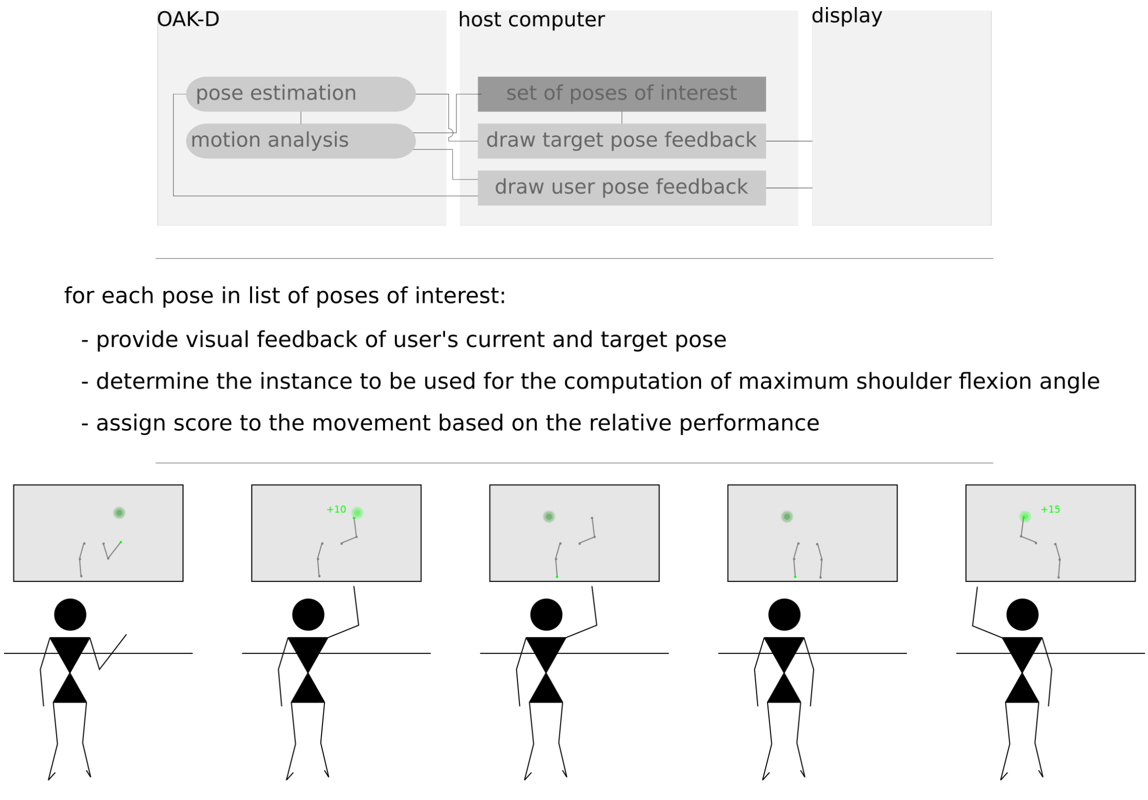


Figure 6: Outline of the proposed user experience for the game-like virtual goniometer.

Future work

The three months frame defined for the competition is taken into consideration in the establishment of the presented expected outcomes. Notwithstanding, pending the materialization of the proposed prototype future studies are to be sought. Namely, the devise of a study of the impact of gamification elements in the user engagement; the extension of the list of poses of interest; the use of facial expression analysis for the score of movement completion; the study of the gamified goniometer as a tool for promoting exercise habits in the population of breast cancer survivors by comparison to the adhesion of a control BCS group to independent exercise promoted through only information dissemination efforts (e.g. printed handouts); the study of human pose estimation methodologies and performance analysis of pose recovery from multi-modal visual data.

Closing Remarks

The OAK-D solution provides a rather accessible opportunity to materialize computer vision and machine learning incredible capabilities, while contributing to both the study of more fundamental methodologies and in the solution of real world problems. Moreover, its ability to locally process streams of visual data via deployed pipelines seems to suit conveniently identified requirements of privacy and transparency, particularly pertinent in a context of producing clinically relevant data. The presented study case constitutes a remarkable opportunity to evaluate the OAK-D in a challenging context that has the potential of benefiting many worldwide.

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Team Capability

A resume summary of the teams members is shown below.

João Pedro Monteiro (jpsm@ieee.org) Holds an MSc degree in Biomedical Engineering from the University of Porto (2012). He is currently pursuing his PhD in Electrical and Computer Engineering and working at the Visual Computing and Machine Intelligence Group within INESC TEC - Instituto de Engenharia de Sistemas e Computadores, Tecnologia e Ciência, a R&D institute affiliated to the Universidade do Porto. His PhD topic is personal health systems for assessment of upper extremity impairments. His main research interests are computer vision, machine learning and medical decision support systems.

André Magalhães (amag1976@gmail.com) Holds a degree in Medicine from the Faculty of Medicine of the University of Porto (2000) with subspecialization in breast cancer (2006). Currently working as surgical physician assistant at the General Surgery Service of University Hospital Center of São João, Portugal; affiliated to the Breast Center, Ambulatory Surgery Unit and Emergency Department, as well as oncoplastic Breast Surgery Team, at Hospital da Trindade.

Luís Teixeira (luisft@fe.up.pt) Holds a Ph.D. in Electrical and Computer Engineering from Universidade do Porto in the area of computer vision (2009). Currently he is an Assistant Professor at the Department of Informatics Engineering, Faculdade de Engenharia da Universidade do Porto, and a researcher at INESC TEC. Previously he was a researcher at INESC Porto (2001-2008), Visiting Researcher at the University of Victoria (2006), and Senior Scientist at Fraunhofer AICOS (2008-2013). His current research interest include: computer vision, machine learning and interactive systems.

Hélder Oliveira (helder.f.oliveira@inesctec.pt) Graduated in Electrical and Computer Engineering in 2004, received the M.Sc. degree in Automation, Instrumentation and Control in 2008 and the Ph.D. degree in Electrical and Computer Engineering in 2013 at the Faculdade de Engenharia, Universidade do Porto, Portugal. Currently working as Senior Researcher at INESC TEC, in the Visual Computing and Machine Intelligence Group (VCMI) and in the Breast Research Group. Invited Assistant Professor at Departamento de Ciências de Computadores of the Faculdade de Ciências of the Universidade do Porto. His research interests include medical imaging, bio-imaging, image and video processing, machine learning, artificial intelligence and 3D modelling

Additionally, the following manuscript is presented as an illustrative line of work:

João Pedro Monteiro, Carolina Lopes, Nuno Duarte, André Magalhães, Hélder Oliveira "Human Pose Estimation, Anthropomorphism and Gamification in the Promotion of Physical Activity among Breast Cancer Survivors". In: International Journal on Advances in Life Sciences, issn 1942-2660 vol. 11, no. 3 & 4, year 2019, http://www.iariajournals.org/life_sciences/. URL: `https://thinkmind.org/index.php?view=article&articleid=lifsci_v11_n34_2019_3`

Team Type

University Team: Joao Pedro Monteiro[1,3], Andre Magalhaes[4], Luis Teixeira[1,3], Helder Oliveira[2,3]

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