Faculty of Computer Science and Information Technology

Cycling Kinematics Analysis using Image Processing

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ABSTRACT

Cycling kinematics are important for cyclists since it helps them to improve their performance and decreased the chance to get injured. Besides, it helps the physiotherapists and sports personnel to perform an onsite quick check. This research is about the analysis of cycling kinematics by using image processing. The data for this project is videos of cyclist cycling with three red markers on the hip, knee, and ankle's joint position. The proposed algorithm successfully detected the manually added red markers for the calculation of the angle of the joints.

ABSTRAK

Kinematik berbasikal penting bagi penunggang basikal kerana ia membantu meningkatkan prestasi mereka dan mengurangkan peluang untuk cedera. Selain itu, ia membantu ahli fisioterapi dan ahli sukan untuk melakukan pemeriksaan semua situasi dengan segera. Penyelidikan ini adalah mengenai analisis kinematik berbasikal dengan menggunakan pemprosesan gambar. Data untuk projek ini adalah video penunggang basikal berbasikal dengan tiga penanda merah pada sendi pinggul, lutut, dan pergelangan kaki. Algoritma yang dicadangkan berjaya mengesan penanda merah yang ditambahkan secara manual untuk pengiraan sudut sendi.

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CHAPTER 1

INTRODUCTION

1.1 Introduction

Nowadays, image analysis is becoming increasingly important and widespread because it can be done more conveniently, rapidly, and cost-effectively (Prats-Montalban et al. 2011). Image analysis is a basic tool for recognizing, differentiating, and quantifying diverse types of images, including grayscale and color images, multispectral images for a few discrete spectral channels or wavebands, and so on (Fernando, A.M. et al. 2015). It has been applied to many fields of science and technology. An image that can be observed by human eyes when it is a two-dimensional image and digital image processing is a process of digital signal processing operations on digital images to retrieve the useful information needed from the image or enhanced the image (Deepak, K. et al. 2018). Digital image processing uses a computer algorithm to do image processing on a digital image where the image is an input, and features or the details of that image will become the output after the processes.

The most common type of discontinuity in a digital image is a point and the most common approach to finding discontinuities is to run an (n x n) mask over each point in the image (Rajiv, K. et al. 2012). The point is found at a location (x, y) in an image where the mask is centered. The concept of point detection is the gray level of an isolated point will have a bit different from the gray level of its neighbors. The point variations are mainly due to both image perspective transformations such as scale changes, image rotations or translations, and illumination changes (Region, C. et al. 2012).

In the kinematic analysis of clinical gait, the location of the various joints of a patient's body is tracked and analyzed for their temporal evolution and possible abnormalities (Yeasin, M et al. 2000). The evaluation of the movement of patients experiencing cerebral palsy, head

injuries, spinal injuries, and stroke can help in the determination of suitable surgical and orthotic interventions. Other than that, the information of joint level motion helps in the evaluation of the prosthetic joint replacement and physical therapy of joint disease in orthopedics. The posture of humans when performing a sports activity will affect their performance and they may get injured if their posture is wrong. Cycling increase the probability of getting injured for human whether the cyclist is an expert, for leisure or commuting. Besides, the points of the body parts that contact the bike can undergo continued amounts of pressure and compression which may cause numbness, pain, and weakness (Physiopedia, 2019).

1.2 Problem Statement

In sports, image processing can be used as an analytical device to define strategic instances in-game or can be used in the broadcast of video to television viewers. This project is to develop an algorithm that can track and analyze the kinematics of a cyclist by recognizing points on the human joints and performing analysis such as limb angles and posture. The cyclist will stick with round colored stickers on the joints and selected portions of the body. While the cyclist is cycling, pictures and videos will be captured. The algorithm can then use the pictures or videos for further processing which is used to analyze joints of human posture such as limb angles and posture. The detection of limb angles and posture can help physiotherapists or medical or sports personnel perform onsite quick checks on the human user to ascertain if the user is exercising using the right methods and exerting correct and safe forces.

1.3 Scope

The scopes focus to complete this project are

- The prototype is mainly used for physiotherapists or medical or sports personnel.
- Assume posture for the upper part of the body is fixed.
- This project will concentrate on the angle for the lower part of the body.

1.4 Objectives

The main objectives of this project are

- To analyze the existing image analysis algorithm that tracks the kinematics of cyclists.
- To design and implement an image analysis algorithm that detects cyclists' joints and tracks the kinematics of cyclists.
- To evaluate the performance of the proposed image analysis algorithm.

1.5 Brief Methodology

The method that converting an image into digital form is known as image processing. Some operations will be performed on the image with image processing to get an enhanced image or to extract some useful data from the image. It is a type of signal dispensation in where input is an image, such as video frame and photograph and output may be image or features related to that image. The image processing system normally involves treating images as 2-dimensional signals while applying already set signal processing methods to them. The fundamental steps in digital image processing are:

1.5.1 Data collection

The process of data collection for the proposed algorithm will be downloading bike fit videos from YouTube and adding 3 red markers on the hip, knee, and ankle joints position. After the video is edited, the raw data will be loaded with software to manipulate and post-process.

1.5.2 Image acquisition

The purpose of image acquisition is to transform an optical image into an array of numerical data which could be later manipulated on a computer. An image must be capture by a camera and converted into a manageable entity before start image acquisition for any video or image processing. This process is achieved by using a suitable camera.

1.5.3 Image pre-processing

Pre-processing functions include those steps that are usually needed before the main data analysis and extraction of data. Other than that, normally these are classified as radiometric or geometric corrections. The pre-processed images will have some noise which should be deleted for the further processing of the image by using algorithms.

1.5.4 Image analysis

Image analysis methods are to extract the data from an image by using an automatic or semiautomatic technique termed as scene analysis, image description, pattern recognition, computer or machine vision, image understanding, and so on. Image analysis is different from other methods of image processing since the result for image analysis procedures is a numerical

output instead of a picture. Besides, deep learning will be utilized to analyze the image. In this project, the joint of cyclists will be added with round coloured stickers manually with video editing software for the video downloaded on selected portions of the body to determine the angle.

1.5.5 Result verification

The accuracy of information depends on the developer's additional work. A lot of metrics has been proposed to compare segmentation results which include volume measures, spatial overlap measures, and boundary measures. The assessment of segmentation quality can consist of two types of evaluation depends on the availability of reference segmentation.

1.6 Significance of Project

There is an existing prototype that used to analyze the performance of the cyclists and find out the way to improve their performance. The purpose of this project is to analyze the kinematics of cyclists by tracking points on the joints and the prototype is developed to help cyclists improve their performance and decrease the chance of getting injured. Other than that, the prototype is used to help physiotherapists and medical or sports personnel perform an onsite quick check on the human user to ascertain if the user is exercising using the right methods.

1.7 Project Schedule

This project starts from 16th September 2019 and ends on 17th April 2020 which will take 215 days to complete. Below show the task and Gantt chart for the project.

Task Name	Duration	Start	Finish
Cycling Kinematics Analysis using Image Processing	**215 days**	**Mon 16/9/19**	**Fri 17/4/20**
Brief Project Proposal	**14 days**	**Mon 16/9/19**	**Sun 29/9/19**
Project Proposal	**20 days**	**Mon 30/9/19**	**Sat 19/10/19**
Research on Topics	7 days	Mon 30/9/19	Sun 6/10/19
Define Methodology	7 days	Mon 7/10/19	Sun 13/10/19
Identify Scope and Objectives	7 days	Sun 13/10/19	Sat 19/10/19
Chapter 1: Introduction	**7 days**	**Sun 20/10/19**	**Sat 26/10/19**
Chapter 2: Literature Review	**21 days**	**Sun 27/10/19**	**Sat 16/11/19**
Finding journals and articles to get more information	7 days	Sun 27/10/19	Sat 2/11/19
Analysis the information	14 days	Sun 3/11/19	Sat 16/11/19
Chapter 3: Requirement Analysis and Design	**19 days**	**Sun 17/11/19**	**Thu 5/12/19**
Collect requirement from expected user	8 days	Sun 17/11/19	Sun 24/11/19
Quick design of the prototype	11 days	Mon 25/11/19	Thu 5/12/19
Chapter 4: Implementation and Testing	**117 days**	**Fri 6/12/19**	**Tue 31/3/20**
Build the prototype	45 days	Fri 6/12/19	Sun 19/1/20
Testing on the prototype	10 days	Mon 20/1/20	Wed 29/1/20
Enhanced the prototype	45 days	Thu 30/1/20	Sat 14/3/20
Testing on the prototype	17 days	Sun 15/3/20	Tue 31/3/20
Chapter 5: Conclusion and Future Works	**17 days**	**Wed 1/4/20**	**Fri 17/4/20**
Making conclusion	10 days	Wed 1/4/20	Fri 10/4/20
Doing Future Works	8 days	Fri 10/4/20	Fri 17/4/20

Figure 1.1: Start date, finish date, and duration for the tasks to complete the project.

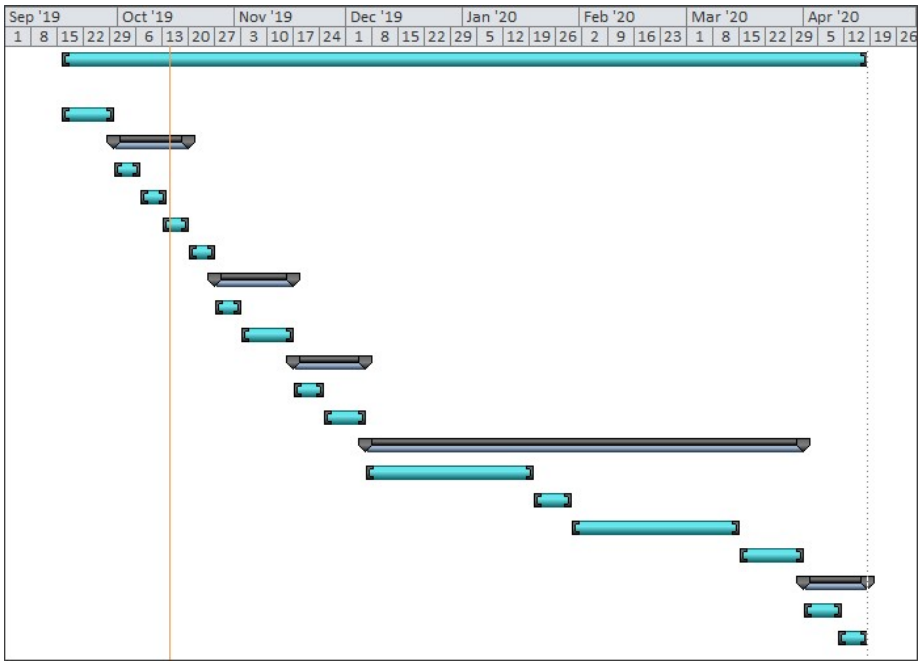

Figure 1.2: Gantt chart for the timeline of the project.

1.8 Expected Outcome

At the end of this final year project, a prototype that can track the kinematics of cyclists by tracking points on the joints and analyses such as limb angles and posture is the outcome for this project.

CHAPTER 2

LITERATURE REVIEW

2.1 Introduction

Statistical nature is an important class of theoretical and practical issues in communication and control (Kalman, 1960) where the issues are separate the random signals from random noise, detect the signals of known form pulse. The Kalman filter can predict a process state at some time and collect feedback in the form of noisy measurements even the precise nature of the modeled system is unknown, and it supports the prediction of past, present, and future states.

In the past few years, human gait analysis using video processing tools has become popular for stroke rehabilitation therapy (Cheng, et al, 2013). Gait and motion analysis systems are commonly used to keep track of the changes in knee joint kinematics and provide visual feedback to the patients for periodical evaluation. Multiple infrared cameras are typically used in 3D motion analysis to record the dimensional positions of reflective markers fixed on the joints of a patient with high accuracy in actual time and calculate the angle of knee-joint accordingly. However, the problems of optical 3D tracking systems are that the system is expensive and difficult to transport. Besides, a subject is walking on a scaled mat with bullseye which is black-and-white markers that fixed on the hip, knee, and ankle joints in the targeted application scenario and the points for object representation are use in point tracking.

Several problems related to sports can be solved by using the scientific approach (Watanabe, et al, 2006). The first step that includes the quantitative measurement of variables is important to the execution of the sport, such as playing golf. An athlete can improve his or her skill levels by referring to the true-life evidence that gains a quantitative measure of golf form and define the relationship between these measurement values and the skill levels, this is

same for the cycling. Sports measurement methods, depending on the sensing device used, can divide into contact and non-contact types. The direct linear transformation (DLT) method which uses images captured by high-speed cameras is the popular example of the non-contact type. However, the contact method employs devices that are attached to the human body, for example, force plates, accelerometers, and gripping-force sensors to generate the data.

2.2 Review of Similar Prototype

To achieve a successful system, a literature review is important since it helps to identify problems that happened in the existing prototype and helps to identify the best approach to achieve the project goal based on the study. There are many similar existing prototypes and below are some of the examples.

2.2.1 Autonomous Gait Event Detection

The objective of the system is to analyze the participant's gait kinematics indicated by the knee angle autonomously (Cheng et al, 2016). The objective of the system will be reached by tracking three bullseye markers that stick on the joint centers of the hip, knee, and ankle of the participant. Figure 2.1 shows the procedure of the system.

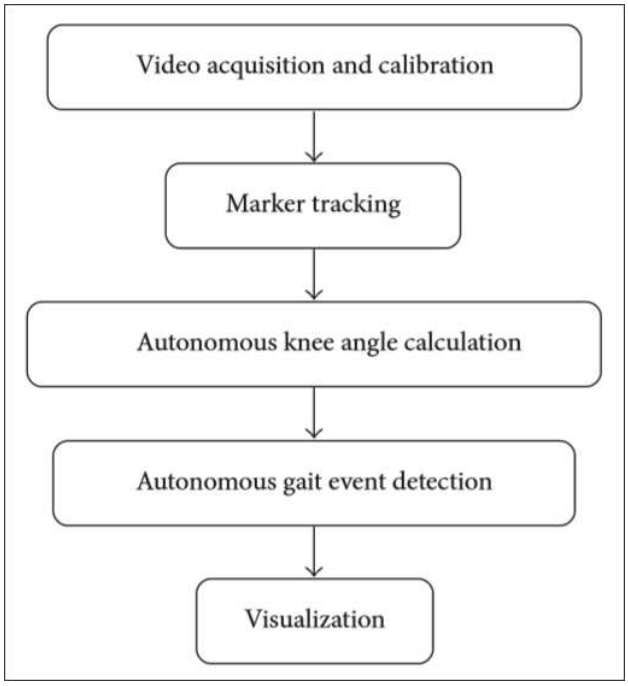

Figure 2.1: System procedure (Cheng et al, 2016).

A video will be recorded about the participants walking on the mat provided with a digital camera fitted on a tripod. Adjustment of lens distortion is done for all video frames by calibrating with a calibration checkerboard. Marker tracking is to find the center coordinate of each marker on the camera-facing leg from other markers frames by frames. Search Area (SA) is set in each frame for every marker where the position and size of the SA are marked by a discrete Kalman filter in the beginning. A full-motion search scheme within the SA is then performed to identify the potential block that most comparable to its marker template and assigned as the tracked marker. The knee angle is calculated autonomously by using the tracked marker's center coordinate which is recorded and all of it in a single frame is plotted to visualize the marker trajectories. Locating the gait events in every gait cycle is needed in order to perform gait analysis. After the marker tracking is being processed, the autonomous gait event detection that tracks all gait phases in every gait cycle is done and labeled as "X". The label "X" is a visualized frame by frame from the heuristically set rules and marked on both marker

trajectories. The system GUI provides all control options and shows the visualization result on marker trajectories, knee angles, and gait detection.

2.2.2 Clinical Gait Analysis

The system provides interpretable outcomes after detects human motions automatically in a fast and easy way without requesting a gait analysis laboratory. The system can be used by the operators who are not an expert in the related field since it is easy to manipulate (Soda et al, 2009). Kinematics analysis is performed with different color markers and there will be a reference marker that used for system calibration.

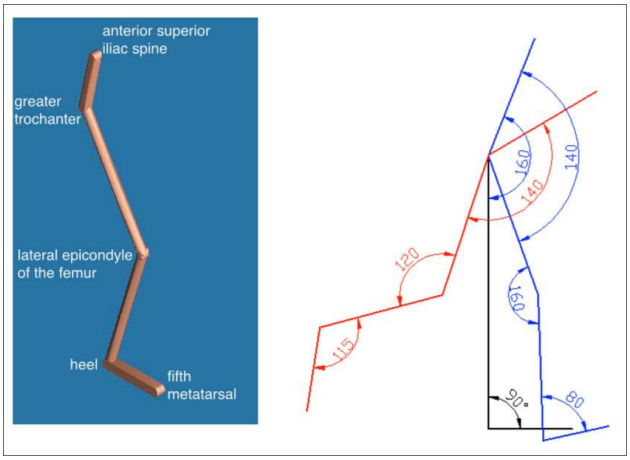

Figure 2.2: A schematic representation of the open kinematic chain which models the subject's leg (left) and the definition of joint angles (right) (Soda et al, 2009).

Ten passive markers, six red and four yellow, is stick on the joints where five on one leg due to interest in performing a 2D gait analysis in the sagittal plane. The five anatomical landmarks have been set certainly as

(i) Anterior superior iliac spine in red marker

(ii) Femur greater trochanter in yellow marker

(iii) Lateral epicondyle of the femur in red marker

(iv) Heel in yellow marker

(v) Fifth metatarsal bone in red marker

A few cycles of the patient's gaits are recorded, and the processing methods used to analyze 2D kinematic gait on the sagittal plane are presents for the next subsection. The markers are tracked to collect kinematic data on patients' gait and follow by setting up the correspondence between markers instances across frames. A point for each marker in one frame has been chosen and then the mean of color data for each marker is calculated by using region growing algorithm for the marker detection. Therefore, the calibration of the system can be carried out and the Nearest Neighbour rule utilizing to calculate the Euclidean distance between each marker, and the pixel is used to track the color pixels in each frame. The motion of the participant can suffer from random perturbation since noise is included in the measurement collected from video, but this issue can be solved by using statistical correspondence methods which is Kalman filter has been applied. After a new frame is processed, the detection mechanism is integrated to collect the new measurements that including marker positions. Occlusion is one of the issues that need to be solved for detecting problems. The markers are pretended to be occluded if they do not have any correspondence in the measurement set for the expected position. The values of hip, knee, and ankle joint angles for the gait cycle in the sagittal plane are calculated by using 2D kinematic analysis, an open kinematic chain is employed to represent the leg of the participant which constitute from three joints and four links. The rigid bodies are represented by the links which connect two consecutive markers that refer to the marker's positions:

- The first link connects markers (i) and (ii)
- The second link connects markers (ii) and (iii)
- The third link connects markers (iii) and (iv)