Design of a Simple Experiment Scheme for Roll-Over Shape Testing

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Abstract

Roll-over shape is the model of the center of pressure transformation in the lower limbs. It is frequently used as the efficiency test of prosthetic feet. In this research, we designed a simple experiment scheme for roll-over shape configuration based on the principal of a beam-moment corresponding with image recording for analysis. Trials on foot prostheses were examined with able-bodied foot. Results obtaining from the designed experiment review similar to the standard protocol and show clinical promise of prosthetic development.

1 Introduction

There are over 50,000 lower-limb amputees in Thailand. The main causes are traffic accident, trap mine, and diabetes. Then the prosthesis in passive design is necessary for livelihood of Thai people. In two decades, Thai lower-limb prosthesis has more improvement by advanced skill from orthopedic physicians. This progress requires a lot of experience from a developer. In the contrary, if we can get the value or calculate some significant parameters from the experiment, it will be easier to improve efficiency of prosthesis design.

A variety of investigators have introduced, aimed at finding the optimal parameters. Roll-over shape by Andrew H. Hansen is an efficient model that is frequently used for testing prosthetic foot [1]. This model is using the way of the center of pressure (COP) transformation in the prosthetic, while it is moved in each contact point. Collected reaction forces can be calculated for a group of COPs on a beam surface. The relationship of COP reaction forces and COP is very useful to determine the foot roll-over shape [2].

In this research, we developed a simple experiment scheme for roll-over shape configuration based on the principal of a beam-moment corresponding with image processing for experimenting on prosthetic foot in two dimensions (2D).

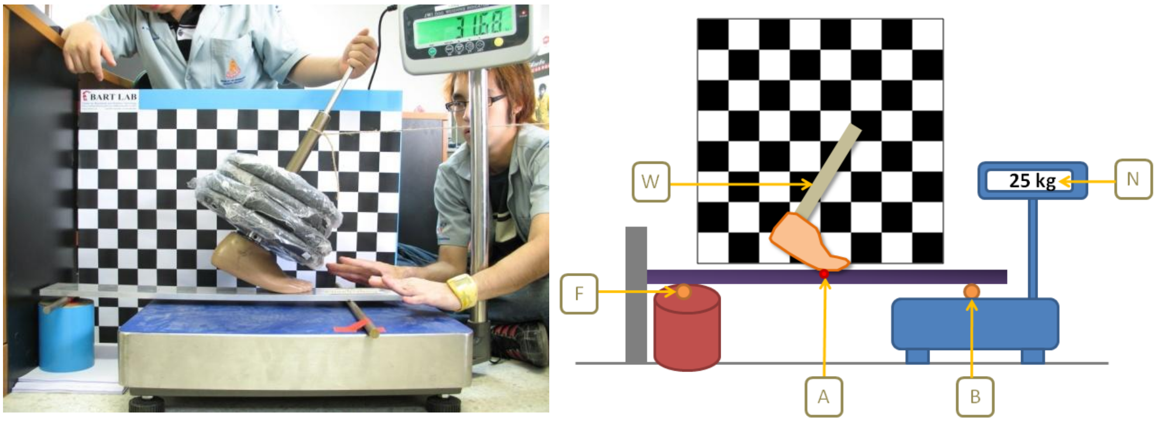
2 Methods

The prosthetic feet provide by the Prostheses Foundation of H.R.H. the Princess Mother. These prostheses are inexpensive, durable, and optimal practice for moderate activity in Thailand. We selected foot size 23 cm and loaded weight 48 kg. This is based on a preliminary study of the mass from 125 Thai people who have size 23 cm foot.

We captured continuously pictures of walking motion on the simple apparatus that composes of a beam bar with two rollers at the end of both right and left sides. One roller is on the floor, and another one is on a load cell as shown in figure 1. Hence COP in each picture can be calculated by using Newton’s law in equation (1 and 2) as follows.

$$\sum Force = \mathbf{0} \qquad (1)$$

$$\sum Moment = \mathbf{0} \qquad (2)$$



A B

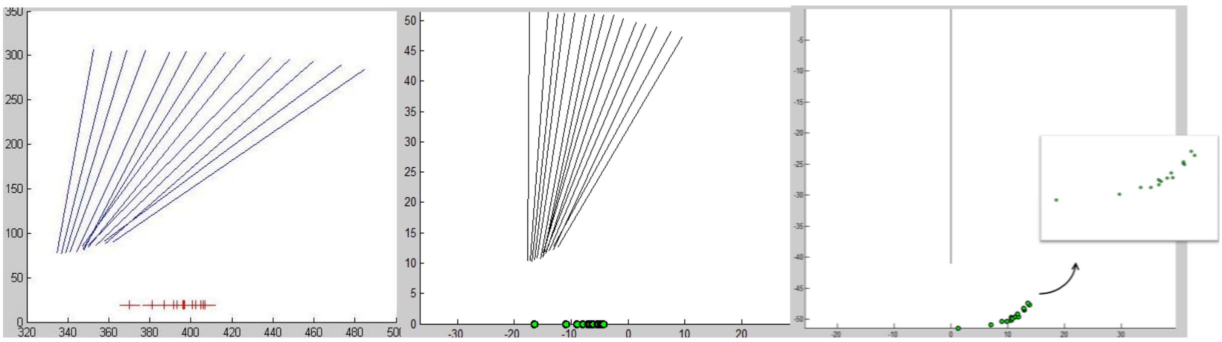
Figure 1: The imitating of human walking of the prosthesis on our apparatus. (Fig.1A) The experiment of walking motion on a simple apparatus was continuously captured. (Fig.1B) The parameters in each picture compose of fulcrum (F), a position of COP (A), a position of reaction force (B), weight of prosthesis (W), and reaction force (N).

To determine foot roll-over shape, we use translation and rotation matrix.

$$Translation\ matrix = \begin{bmatrix} \mathbf{1} & \mathbf{0} & X \\ \mathbf{0} & \mathbf{1} & Y \\ \mathbf{0} & \mathbf{0} & \mathbf{1} \end{bmatrix} \quad (3)$$

$$Rotation\ matrix = \begin{bmatrix} cos\theta & -sin\theta \\ sin\theta & cos\theta \end{bmatrix} \quad (4)$$

From the figure 1, all of parameters are based on a room coordinate system. To approach the shape, we changed the coordinate system by using translation matrix (3) to transfer ankle and knee trajectories into the sagittal plane and transfer COP into a laboratory-based coordinate system. We transferred the data into a shank-based coordinate system by using rotation matrix (4). COP in shank coordinates to draw out the roll-over shape as shown in figure 2.



A B C

Figure 2: Foot roll-over shape calculation. (Fig.2A) Ankle and knee trajectories are on the sagittal plane, and COP is on the foot plate. Data is in a room-based coordinate system. (Fig.2B) Data was transformed into the laboratory-based coordinate system. (Fig.2C) Data is transformed into the shank-base coordinate system and drawn out COP to show foot roll-over shape.

3 Results

The experiment is conducted to investigate the accuracy of the foot roll-over shape acquired from our system. This system consists of a load cell (JADEVER JWI-600), foot plate (aluminum 6063), and two rod pins (copper) [3]. In order to investigate, we compared our design with the efficiency device by using a prosthesis which is the same model with the Andrew H. Hansen's system. The prosthesis imitates human walking to approach foot roll-over shape. While it has been moving, the data will be recorded. The data is used for calculating the series of COP then transfer them to shank-based coordinate system. The foot roll-over shape of forward progression from this experiment was shown in figure 3. There are twenty positions of COP in a shank-based coordinate system.

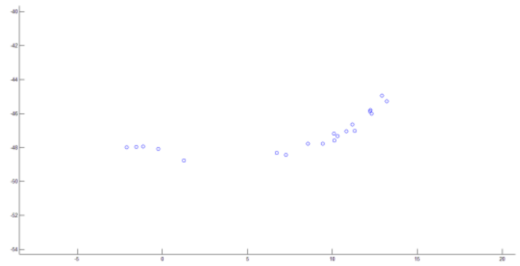


Figure 3: The foot roll-over shape of Prostheses Foundation foot size 23 cm.

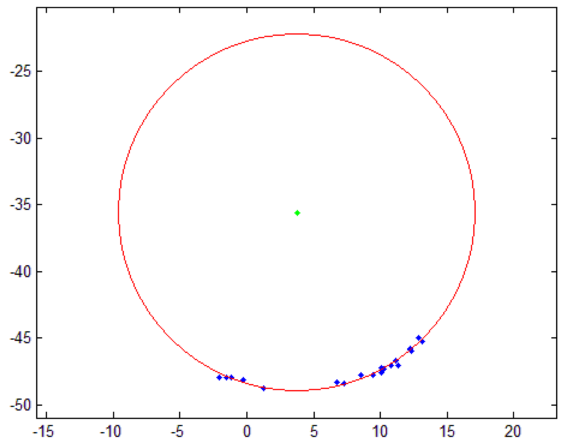


Figure 4: The radius of curvature of Prostheses Foundation foot size 23 cm.

The radius of curvature from Prostheses Foundation foot size 23 cm in this experiment is 141 mm and from Prostheses Foundation foot size 25 cm in Andrew H. Hansen's system is 237 mm. Then the difference of radius of curvature between both experiments is 35% [4].

4 Discussion

The efficiency of this system can be evaluated by comparing the foot roll-over shape in the same prosthesis with Andrew H. Hansen's system. The roll-over shape tends to be alike Andrew H. Hansen's results. Alignment of the COP is the normal distribution on the middle foot, and it is crowding distribution on toe and heel part. The curve of radius in foot roll-over shape from our experiment's results seems less circular 35% than the curve of radius predicted by Andrew H. Hansen's system as shown in figure 5.

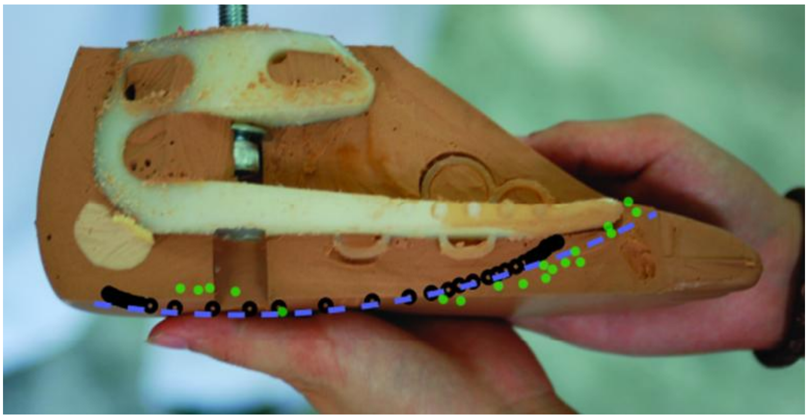


Figure 5: Foot roll-over shape from our system compare with Andrew H. Hansen's shape.

- Human ankle-foot shape
- Foot roll-over shape of Prosthesis Foundation by Andrew H. Hansen's system
- Foot roll-over shape of Prosthesis Foundation by our system

The accuracy of this system can be improved by reducing some of human errors and material errors. The main cause of human errors will be occurred when we set the system. These errors could be from:

- This system uses many parts for setting, and it requires attention and some technique of the examiner. For example, the level of foot plate needs to be arranged equally by using water's level.
- It might be error from uncertain moving of the prosthesis.

For material errors, one of them is from the camera's lens. The lens's shape is curved. The pictures that use for analyzing are through the lens and obviously provide error of distance.
The simple model for foot roll-over shape testing could be useful in Thai prosthetic rehabilitation. This system could reduce the time that researchers spend to develop the prosthesis because it is convenient to install. The material is easy to find in a local area and most importantly the setup is easy and practical.

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