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Setting up a Human Motion Analysis Laboratory: Camera Positioning for Kinematic Recording of Gait

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Abstract

This article compares the techniques used for camera positioning in a study room, proposing optimized data collection for three-dimensional analysis. This study analyzed the usable recording volume of three different video camera layouts: six equidistant cameras (C6), 8 equidistant cameras (C8E) and 8 cameras using enhanced positioning techniques (C8EP). In the last configuration, we attempted to place the cameras in certain locations in the room so that they had the same capture volume. It was observed that the volume of the 8 equidistant camera layout remained practically the same as that using the 6 camera layout (C6=10.579 m^3 C8E x=11.565 m^3). Regarding the enhanced positioning layout (C8EP), a 37% gain in usable walkway length was obtained, along with a 14% gain in width, 34% in height, and a consequent increase of 110% in total volume (22.247 m^3). Although most modern kinematic analysis software have tools that are able to fill in the markings trajectory, the enhanced positioning camera layout provides more accurate information and data interpretation, besides ensuring better usage of rooms with restricted dimensions. The considerable gain in vertical dimension allows for the evaluation of performed activities at a higher level, such as those involving the upper limbs or steps.

Keywords: Motion analysis; Three-dimensional analysis; Kinematics motion; Setting up a motion laboratory; Gait analysis

Introduction

The Kinematic analysis of gait using three-dimensional analysis laboratories utilizes a system of cameras in standard fixed positions that capture the movement of reflective markings attached to the skin of the individual, forwarding it to a computer in order to create three-dimensional movement simulations, models and visualization of real movements in a virtual environment. At least three markings, along with the definition of joint centers and Euller angles in a calibrated system, are necessary to describe the movements of each body segment in one possible solution to this issue.

The arrangement of the cameras along the walkway should be able to capture the movement of the markings in the sagittal, frontal and transverse planes; the space interval in all this three dimensions defines the recording volume where the gait must occur. There should be a sufficient number of properly positioned cameras so that all markings may be seen at all times by at least two of the cameras. When this condition is not met even on short sections of the walkway, more modern movement analysis resources should be used that have an interpolation tool, which fills in the markings trajectory in those sections by way of simulation and animation based on mathematical algorithms [1].

The location where the cameras will be positioned and affixed depends on certain factors: the size of the analysis room where the study will take place, the type of study, and the number of available cameras as well as camera characteristics (lens, sensibility), sizes of the markings and also experimental factors, like luminosity. Depending on the room size, the cameras should be arranged as far as possible from the walkway, so as to increase the range of view that will capture the movement of the markings, given the markers' size is large enough to be visualized [2,3]. The evaluation of human gait requires a walkway with a minimum of 10-12-steps (corresponding to at least eight meters), while the evaluation of movements like jumping and throwing tasks do not require as much space [4]. Although improvement of gait capture only requires adequate length and width, such motion analysis system may be used for vertical movements too, thus an improvement in height is also desirable.

One problem faced in this study occurred during the setting up of the motion analysis laboratory. The building where it was to be located was not originally designated for this purpose, thus, the area available to organize the laboratory measured 8m long by 7.2m wide, and the walkway for recording movement measured 4.50 m × 1.50 m. All evaluations had to be performed within these pre-defined dimensions.

Objective

The aim of this study was to compare a camera arrangement alternative to the usual position of 6 or 8 cameras in regular intervals for a motion analysis laboratory with the goal of increasing kinematic data collection.

Method

With the room set and the total number of cameras already acquired, all focus was put on the best location to affix them. Some important points must be taken into account to facilitate this choice, regardless of the type of study.

Using six cameras:

- The typical arrangement for 6 cameras requires that the walkway used for data collection (where the subject is required to walk) be located in the center of a rectangular room, equidistant from the walls in the longitudinal and transverse axes of the ground plane. The logical reasoning is that the cameras should occupy the midpoints of the walls at the beginning and end of

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the walkway, while the sidewalls are divided into 3 equal parts by the other two cameras (Figure 1a).

Using 8 cameras with 2 alternative camera arrangements:

- In the first alternative arrangement, the walls at the ends of the walkway have a centralized camera. The same positioning is used on the sidewalls. The four remaining cameras are positioned in the corners of the room (Figure 1b). With this arrangement, each camera covers only a portion of the walkway, not the full length of it, which is more evident with cameras C3 and C7.
- In the second option of alternative arrangements, four cameras remain positioned in the corners of the room and in the center of the walls near the end of the walkway, and the remaining two are placed on the sidewalls, with a distance of about 2 meters from the opposite vertex (Figure 1c). The choice for this form of placement is based on the idea that all cameras should display the greatest possible extent of the walkway. To achieve this, markings are put on the ground to allow for the adjustment of each camera (Figure 2).

In order to quantitatively compare the proposed camera arrangements, the dimension "volume" was used, which is enough space to collect images and enough space for a study that allows the simultaneous viewing of all cameras. The calculation of the volume was obtained from the maximum length, width, and height obtained by each arrangement.

Results

Table 1 show the linear measurements from the reference point of the walkway where measurements were initially taken. The change in positioning and number of cameras led to a 37% increase in the usable length of the walkway (from 3.46 m, figure 1a, to 4.77 m, figure 2a). There was a 14% gain with respect to the width of the walkway, and a 34% gain in vertical dimension. The capture volume increased 110%. Note that changing from six to eight cameras placed in an equidistant manner, left the useful area for capturing the markers virtually the same (Figures 1a, 2a and 2b).

Discussion

Since the dimensions of the study room were already fixed and there were eight available cameras, the challenge faced by this study was to optimize the capture environment to be able to view a 10.59m² walkway. The rearrangement of the cameras attempted to allow all cameras to visualize the same volume, which resulted in a considerable increase in the length, width and height of the useable recording area. Increased videotaping accuracy is obtained with a larger number of cameras focusing on the same point or with the object being near to the camera [2].

Although the positioning of cameras was based on markers on the floor, this strategy proved useful to optimize assessment of human gait once this study's usable volume was increased due to enhancement of linear measurements in all three dimensions: latero-lateral, anteroposterior and in the height in the alternative 8-camera arrangement. While gait study only requires an increase in the length and width of the recording area, the increase in vertical dimension capture allowed us to use the laboratory for other studies such as the study of upper limb movements and the use of steps [1].

Bontrager [4,5] suggests another way to ensure the best location for positioning cameras in the study room is through the use of a laboratory

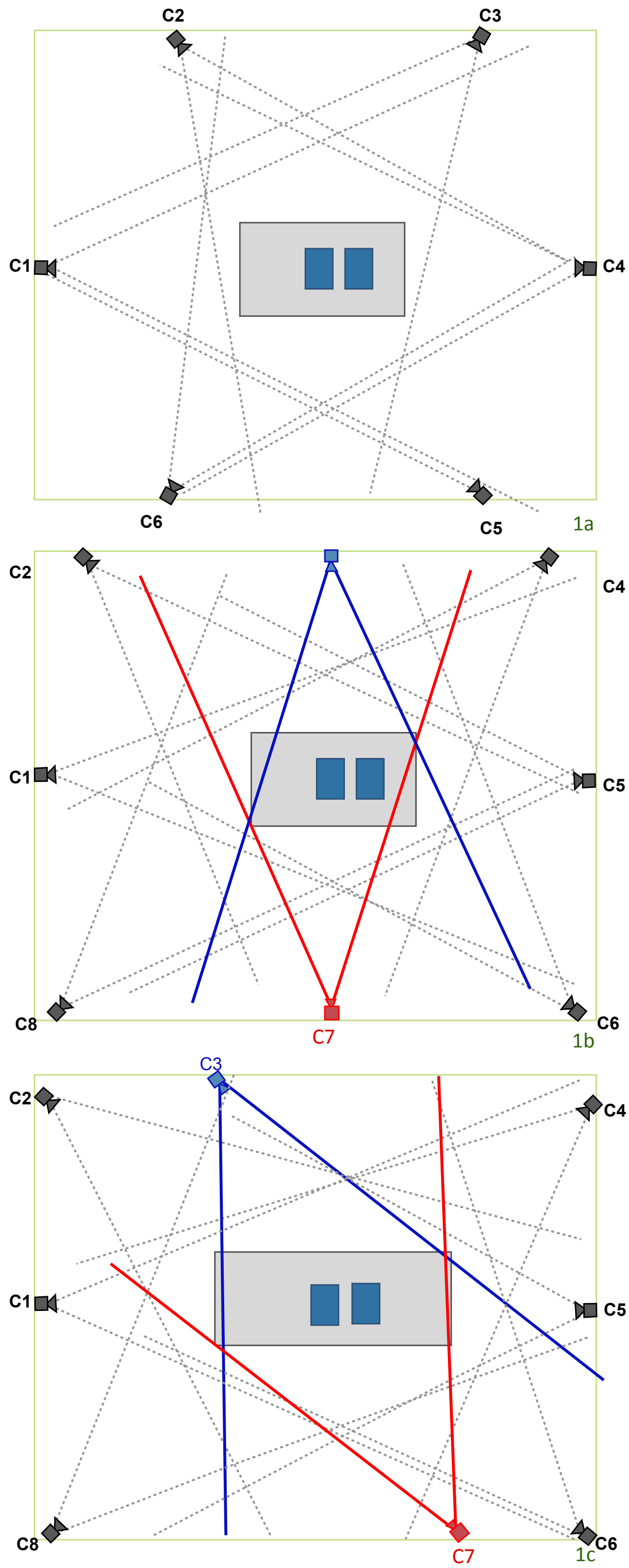

Figure 1: 1a –Positioning of 6 cameras equidistant to each other. Note the length and width of the recording area. **1b** – Length and width of the recording area with 8 cameras in the same positions as in 1a. **1c** – Positioning of the cameras with the goal of achieving optimal visualization of the entire central area of the study room. Both useful length and width increased considerably.

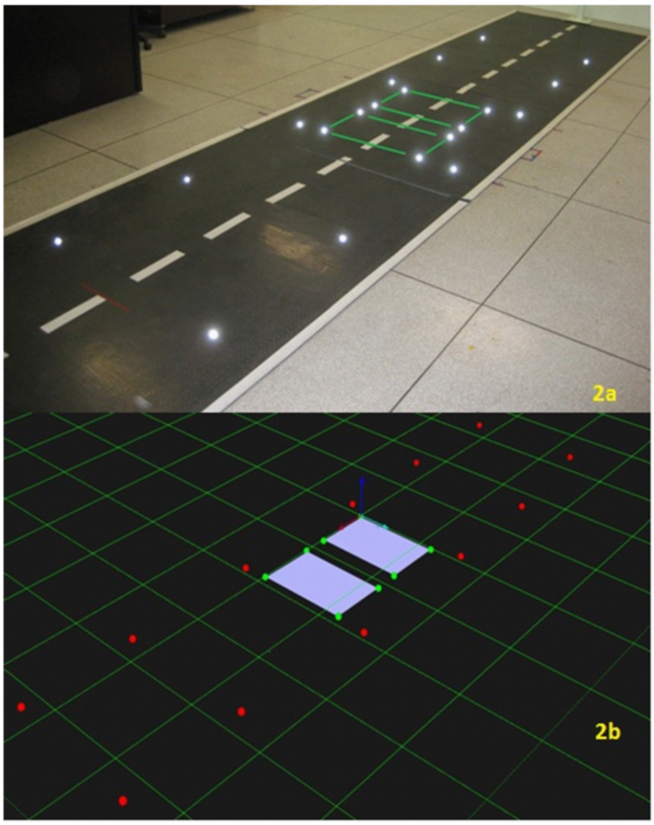

Figure 2: Markers placed along the walkway for kinematic recording. Each camera was positioned so as to offer optimal visualization of the markings on the floor, shaping the data collection walkway. 2a: Positioning of the markings on the floor. The dotted lines in the center of the walkway connect the vertex markings of the force platform. 2b: 3D imaging of the illuminated dots captured by the set of cameras.

	Longitudinal*	Transversal*	Height*	Volume**
6 equidistant cameras	3.465	1.966	1.553	**10.579**
8 equidistant cameras	4.382	1.793	1.472	**11.565**
8 cameras with optimal positioning	4.775	2.241	2.079	**22.247**

Subtitle: *assessed in meters, ** assessed in cubic meters

Table 1: Linear measurements in three directions and capture volumes for each camera arrangement.

floor plan to scale, by cutting isosceles triangles with an acute angle similar to that of the camera viewing angle, and positioning them on the laboratory drawing to determine the position with better coverage of the motion analysis area. The locations of the cameras are marked on the scale drawing to obtain the real position coordinates of the camera in the laboratory. Given the availability of electronic resources that allow for the construction of models of overlapping cones observed by each camera and the instant calculation of overlap, it seemed pointless to use a method that required manual calculation. This method proposed by Bontrager disregards that the increased distance between the object and the camera implies a reduction in recording accuracy, which can be compensated electronically by changing the collection parameters (exposure time and camera sensitivity). It could be argued that semicircular arrangement of 4 cameras at both sides of the walk way might produce a larger capture volume [3,6]. We did not consider this possibility because we did not use tripods to support the cameras, so they would have to be affixed to the ceiling, thus more subject to vibration and imprecise recordings.

In short, arranging the infrared cameras so that all have the best range of view of the walkway infers an increase in linear capture dimensions of length, width and height, resulting in increased usable volume, which enables the laboratory to be used not only for gait studies, but also for other analyses of motion. The disadvantage of this arrangement of cameras we describe here is the higher cost than the 6 camera setting, but this cannot be said in relation to the use of 8 cameras in regular intervals.

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