Aug 17, 2019

Gait analysis using augmented reality markers

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1 Works for me dx.doi.org/10.17504/protocols.io.qkzdux6

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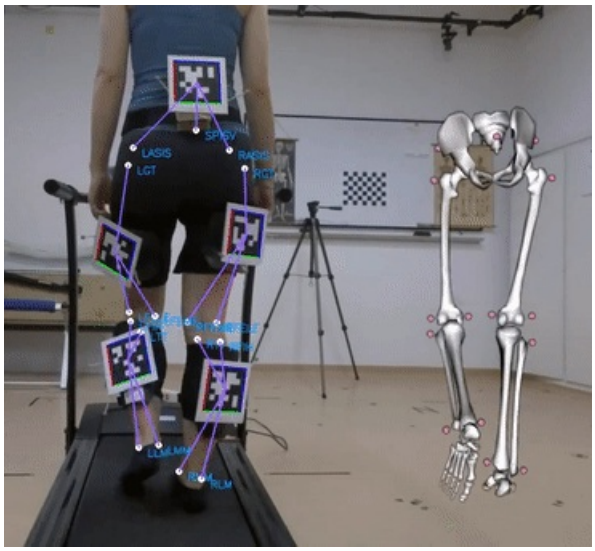
ABSTRACT

The protocol provides guidelines, preparation and execution instructions to perform and process a gait analysis trial by a novel motion capture method using virtually calibrated anatomical points tracked by augmented reality (AR) markers.



GUIDELINES

Marker preparation

Use wide elastic bands to fix markers on the body segments in order to minimize soft tissue artefact.
Adjust the measurement setup so that all markers are continuously visible by the camera.
During anatomical calibration, the marker on the calibration wand and the marker of the calibrated body segment needs to be visible by the camera.

Camera

The accuracy of AR marker pose estimation depends mainly on the quality of camera calibration, which eliminates optical distortions and sets the resolution of input images and marker size on the image in pixels. For the AR marker detection algorithm, a high shutter speed is important to avoid unrecognizable blurry images at faster motions. From the viewpoint of gait analysis, the highest possible frame rate (fps) is required for high temporal resolution. It is also essential for the camera to have a fixed zoom and fixed focal length because camera calibration is valid for fixed values of these parameters.

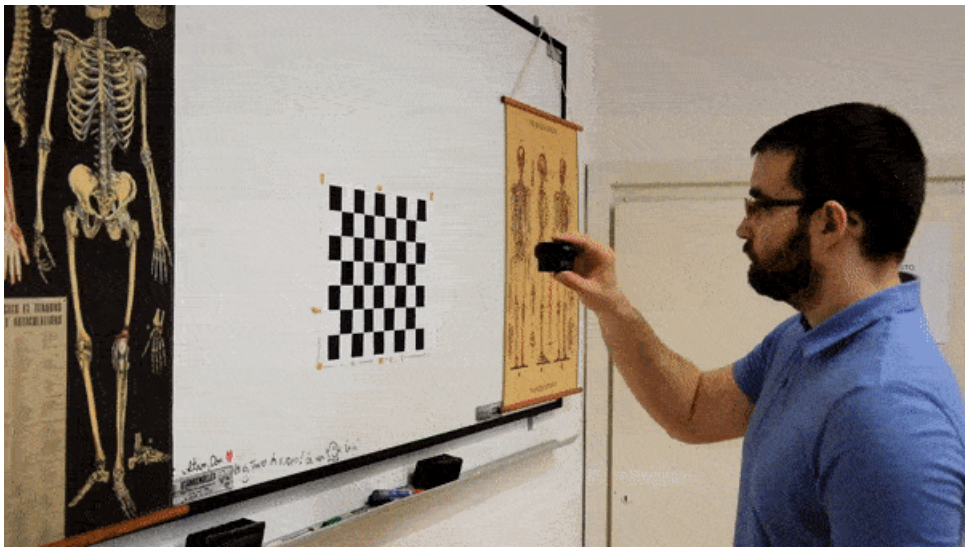
MATERIALS

NAME	CATALOG #	VENDOR
GoPro Hero 5 Black action camera	View	
AprilTag AR marker detection software	View	

NAME	CATALOG #	VENDOR
Custom software to perform homogeneous coordinate transformation to calculate the coordinates of the calibrated anatomical points relative to the AR markers		
AprilTag markers rigidly attached to a rigid bent plate (e.g. commercial shin protectors) that are fixed on the body segments using wide elastic bands		
OpenSim biomechanical analysis software	View	

BEFORE STARTING

The camera used needs to be calibrated using e.g. OpenCV (https://docs.opencv.org/2.4.13.4/doc/tutorials/calib3d/camera_calibration/camera_calibration.html)



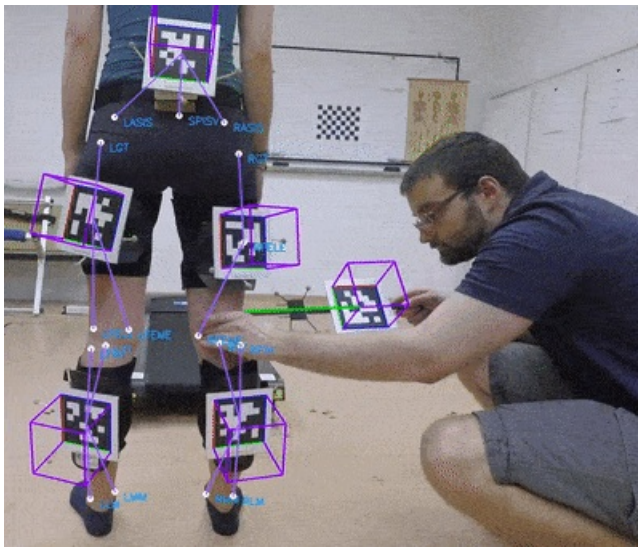
Before the measurement, make sure to set the camera options to the values that were used for camera calibration. A few settings for cameras and camera calibration values can be found in the table below:

Camera	Resolution*	Frame rate (fps)	Shutter speed	Focal length (in pixels)	Distortion parameters**
Kinect v2 (color video recording)	FullHD (1920x1080 pixel)	30	cannot be set	1034.68	k_1: 0.0312 k_2: -0.0450 k_3: 0.0049
GoPro Hero 4 Silver	FullHD (1920x1080 pixel), narrow mode	60	cannot be set	1641.94	k_1: -0.2971 k_2: 0.1752 k_3: -0.0755
GoPro Hero 5 Black	2.7k (2716x1524), linear mode	50	1/200	1483.71	k_1: 0 k_2: 0 k_3: 0
GoPro Hero 5 Black	4k (3840x2160), wide mode	25	1/100	1775.89	k_1: -0.2534 k_2: 0.0894 k_3: -0.0167

*Modes in GoPro cameras refer to the field of view option of the device; Kinect v2 has only a fixed wide field of view
**p_1 and p_2 distortion parameters are equal to 0 in each setup. For details see OpenCV camera calibration manual.

1 Attach the AR markers on the corresponding body segments (for gait analysis: pelvis, thighs and legs)

2 Start recording and perform anatomical calibration on the subject using the pointer after palpating the calibrated anatomical points.



3 Record the gait trial.

4 Upload the video takes to a computer.

5 The calibration and gait trial video files are processed offline by the image processing software where the frames of pointing to anatomical landmarks are selected manually.

6 After this manual post processing a file is available with the calculated marker trajectories during the trial in a standard .trc file format.

7 A third party open-source biomechanical analyzing software (OpenSim) can be used to calculate gait parameters.