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Cross-Validation of an Infrared Motion Capture System and an Electromechanical Motion Capture Device

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ABSTRACT

The current research conducted a cross-validation between an infrared motion capture system and an electromechanical motion capture device. No differences were found between the motion capture methods in shoulder and elbow angles. However, differences were found between the motion capture methods on distances of hand movements and actor location in space. Results of the current study indicate electromechanical motion capture devices are too inaccurate to use for validating digital human models unless the ultimate application of the model does not require millimeter accuracy or an absolute location in space. If one is primarily interested in joint angles, and distances are secondary, an electromechanical device is acceptable.

INTRODUCTION

Since the late 1980s, motion capture technology has been widely used for animation in the video gaming and movie industries [1]. However, motion capture and the analyses of human movement for scientific purposes began in the early 1800s. In 1836 Weber and Weber reported distance and reaction times during human locomotion [2]. In the 1870s, Marey and Muybridge pioneered photographic motion capture techniques while other researchers calculated body joint forces and energy requirements (e.g., Braune & Fisher) [4, 5, 3]. The most recent motion capture technological innovations have been used in the study of military applications or in orthopedic rehabilitation [3]. For example, researchers have applied motion capture techniques to troop movements as well as prosthetic device designs. Mundermann, Corazza, and Andriacchi provide a more thorough review of motion capture history [3]. In comparison to kinematics and orthopedic medicine, digital human modeling is a new scientific endeavor. While motion capture has been used for kinematics for almost two centuries and rehabilitation for almost a century, motion capture may also prove an invaluable tool for digital human modelers. Motion capture techniques can provide accurate data to verify movements generated by digital human models.

Optical motion capture systems are believed to have, “an impressive ability to replicate gestures” [6]. Indeed, one manufacturer claims an accuracy of 0.8 mm. Portable exoskeleton electromechanical motion capture devices are an alternative to optical systems. Electromechanical motion capture devices use internal gyroscopes and potentiometers to calculate rotations of the potentiometer centers in relation to one another.

ADAVANTAGES AND DISADVANTAGES

We (the authors) have conducted motion capture research in a variety of conditions primarily for ergonomics analyses (see Authors’ Note). Our anecdotal experience with each motion capture method has demonstrated advantages and disadvantages for each. While both require training, a savvy researcher can probably learn a system’s operation from its respective manual.

Infrared motion capture systems are usually more expensive to purchase, house, and maintain with electromechanical devices costing a fraction of infrared systems [7]. Comparatively, the electromechanical device used in the current study cost approximately one-fifth the purchase cost of the infrared motion capture system. However, infrared motion capture studio space can be hired and electromechanical devices can be rented for reasonable rates. Depending on the number of actors and the number of moves to be captured, infrared studio space prices range from $3,500 to $5,000 per 8 hour work day [8]. An electromechanical device can be rented for $5,900 per 24 hour day [9].

Electromechanical motion capture devices require collecting anthropometric data and entering the measurements into a calibration file which is used to interpret and analyze potentiometer readings and construct digital actors. Infrared motion capture volumes do not usually require anthropometric data collection, but do require considerable set up effort and time.

Based on our experience, setting up a motion capture volume and collecting data in a natural environment outside the laboratory is sometimes not feasible due to space, time, economic constraints, or environmental conditions. Alternatively, it is not always plausible to replicate natural environments in motion capture laboratories. For example, assembly line workstations on factory floors operate in narrow time windows within limited spaces. It is often too expensive to stop an assembly line in order to set up a motion capture volume. Replicating an assembly line in a controlled laboratory setting is not always practical, especially for large objects and highly specialized assemblies.

We have found that with practice, a small infrared motion capture volume (e.g. 8 cameras or less) can be constructed from initial camera placements to calibration in less than two hours. A volume can remain in place indefinitely with recalibration taking only a few minutes. Conversely, a full-body electromechanical motion capture device can be placed on a participant and calibrated in approximately 30 minutes with practice. An idiosyncratic calibration file can be stored and used again on the same participant with recalibration also taking only a few minutes. Unlike most infrared systems, electromechanical devices can be used in direct sunlight and in environments with highly reflective surfaces (e.g., around mirrors, chrome, glass, etc.,). Other environmental variables such as machinery vibrations transferring through architectural structures and drastic temperature changes in high humidity conditions causing condensation on camera lenses can also pose problems for infrared systems. Moreover, the reflective markers used with infrared motion capture systems may fall off the participant. Exoskeleton motion capture devices are more cumbersome because the exoskeleton may collide with, or get caught on, objects in the environment and if not properly attached to a wearer, the potentiometers may slip or move. The exoskeleton limits a wearer’s range of motion and if the slip linkages between the potentiometers are over extended or fully collapsed, the linkages can bind. Additionally, exoskeleton motion capture devices weigh up to 6.35 kg. Lastly, while participants are confined to a limited volume with infrared motion capture systems, wireless exoskeleton motion capture devices can be used in conjunction with wireless networks or laptop computers to give them an infinite range.

Because electromechanical motion capture devices are not restricted to a defined volumetric space, they may afford better ecological validity than optical systems when used in real-world environments, provided the range of motion is not exceeded. However, depending on the individual wearer’s level of physical fitness, the weight of the electromechanical motion capture device may interfere with the ability to perform natural movements, and depending on the environment and task, the bulkiness of the exoskeleton may sacrifice any possible advantages.

Because infrared motion capture systems and electromechanical motion capture devices both appear to have potential benefits, the current research sought to cross-validate an electromechanical motion capture device with an infrared motion capture system. An initial mechanical validation of the infrared motion capture system was conducted, followed by comparisons of the infrared motion capture system data to the electromechanical motion capture device data for hand motion distances, shoulder angles and elbow angles, as well as an analysis of position (actor location in an X, Y, and Z volumetric space). There was no difference found for joint angles between the systems, but differences were observed for limb movement distances and for actor location in three dimensional space.

METHOD

PARTICIPANT AND SAMPLE

One 43-year-old male participant was used for data collection. He is a coauthor on the current paper and a fellow researcher. Since the goal of the current project was to cross-validate two devices, measures for the devices are compared for 4 static shoulder postures for each arm, 22 hand motion sub-movement distances as part of one motion for each hand, and two locations in a volumetric space.

APPARATUS

A 12-camera configuration MotionAnalysis (EVaRT 4.2) infrared motion capture system with a 60 frame per second sampling rate was used for infrared motion capture. The calibrated volume was 3,600 mm × 2,400 mm × 200 mm, located in the center of a dedicated space of 7,620 mm × 7,620 mm × 2,900 mm in the Human Factors and Ergonomics Laboratory at the Center for Advanced Vehicular Systems at Mississippi State University. All infrared data point values were collected using 6.096 mm reflective marker balls. Simultaneously, an Animazoo Gypsy Suit wireless motion capture system with a reported 120 frame per second sampling rate was used to collect the electromechanical data. The electromechanical device was placed on the participant and calibrated as per the instruction manual. Reflective markers were placed as near the potentiometers of interest as possible and all were located approximately the same in relation to each potentiometer.

PROCEDURES

Infrared system validation

Initially, the infrared motion capture system was calibrated as per the instruction manual. A measuring tape was used to position two reflective markers 3,600 mm apart on the floor. The infrared system indicated the markers were 3,600 mm apart and X, Y, and Z coordinates were recorded for the markers. The system was turned off and restarted. The indicated distance (3,600 mm) and the X, Y, and Z coordinates of the markers were the same after the system was restarted. Reflective markers were also placed on a carpenter's speed square and the system returned the correct angles. Since all measures were identical, without deviation, no statistical analyses were performed and the data from the infrared motion capture system was believed to be valid and reliable.

Extrapolation and interpretation

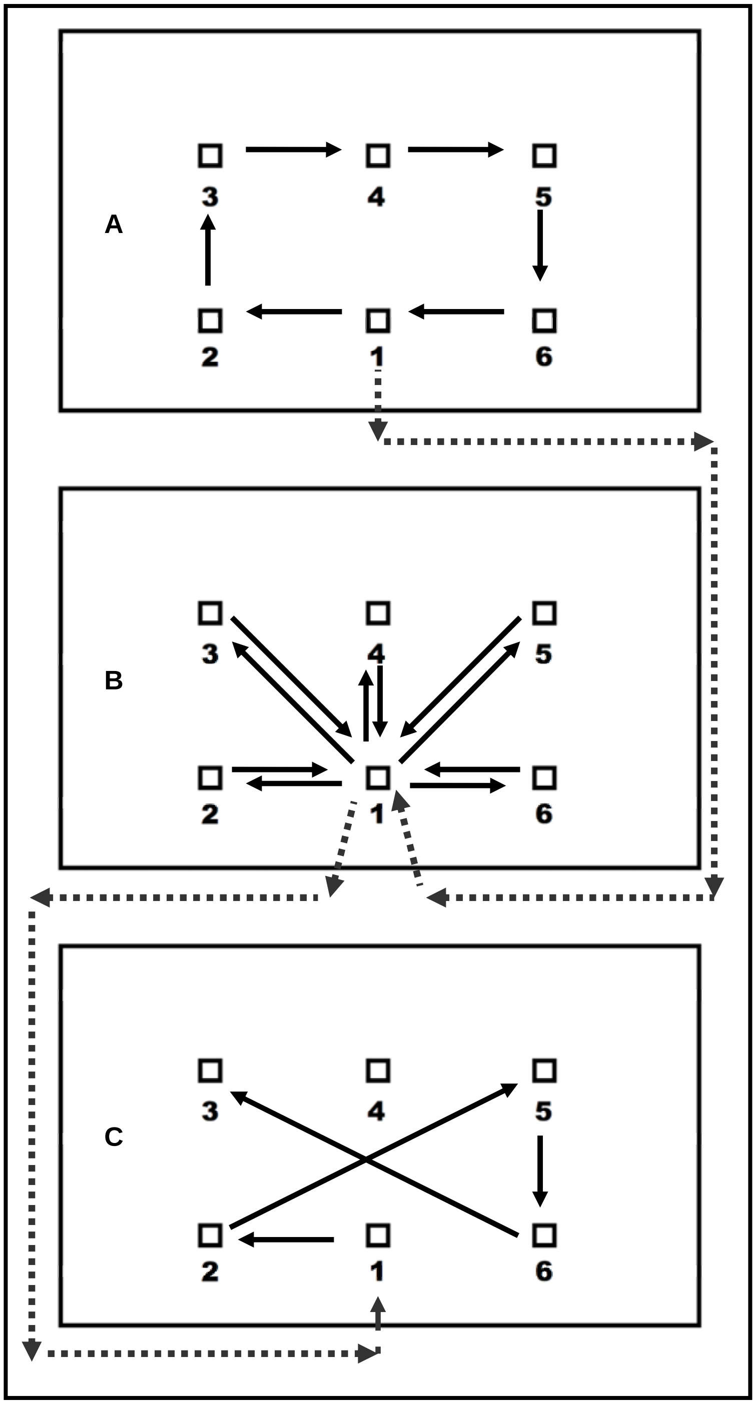
Movements of the electromechanical device generated rotations recorded by potentiometers. The infrared system recorded coordinates of the reflective markers, then calculated angles between segments defined by sets of markers. An algorithm was used to convert the potentiometer rotations into X, Y, and Z coordinates. The algorithm traverses the hierarchical data, applying composite rotation matrices to the offsets defined in the wearer's calibration file. Given the differences in angle calculation methods between the motion capture systems, the shoulder angles were adjusted by 180° and the elbow angles were adjusted by 90° for comparison. Four elbow angles and four shoulder angles, 44 hand motion distances (22 per hand), and two spatial reference points were compared.

MEASUREMENTS OF INTEREST

Hand motion distance

The sampling rates were 120 fps for both methods. The participant stood at an elevated table. Six pegs placed approximately 305 mm apart were attached to the tabletop in a rectangular configuration (see *Figure 1*). The pegs were 254 mm × 254 mm squared × 508 mm tall. Initially, the participant clapped his hands and touched each peg with the center of his hand in a clockwise fashion (see the top illustration in *Figure 1*), after which, using the first peg as the initial and final point of contact, the participant touched each peg (e.g., from peg 1 to peg 2 and back to peg 1 followed by peg 3 and back to peg 1, etc., see the middle diagram in *Figure 1*). The participant then touched the pegs diagonally from corner to corner (peg 2 to 5, and 6 to 3, see the bottom diagram in *Figure 1*). Each motion sequence depicted in the *Figures 1 diagrams* was performed in one continuous movement and the data was collected in one file. We extracted one frame from each motion capture system for each hand clap and each peg contact point. Hand movement distance

Figure 1. Peg Configuration and Movement



**note. Figure 1 illustrates one dynamic fluid movement. The starting point for the movement was a hand clap followed by touching peg 1 at the top diagram (A) and the stopping point was a hand clap after touching peg 3 in the bottom diagram (C). As illustrated by the solid arrows in the top diagram, the participant placed his hand from peg 1 to peg 2, from 2 to 3, from 3 to 4, from 4 to 5, from 5 to 6, from 6 to 1. Once the participant's hand returned to peg 1 in diagram A, he immediately touched the pegs as illustrated by the solid arrows in the middle diagram (B). Once the participant moved from peg 1 to peg 6 and back to peg 1, he immediately touched peg 2 as illustrated in the bottom diagram (C).*

between each contact were calculated. Frames were chosen based on apparent contact with the peg. In other words, frames were chosen where the actor appeared to touch the pegs. Distances from each motion capture method were compared for each movement.

Shoulder and elbow angles

The sampling rates were 60 fps and 120 fps for the infrared motion capture system and the electromechanical device respectively. Angles from 2 different shoulder postures and 2 different elbow postures for each arm were collected (8 total). A carpenter’s speed square was used to position the participant’s elbows (upper arms relative to the lower arms) and shoulders (upper arm relative the torso) at 90° and 45° postures. See *Figures 2, 3, 4,* and *5* for an illustration of the positions. Although the postures were static, the data for those postures were collected in one continuous session. In other words, the participant modeled all postures in succession and each motion capture system generated one data file. The frames were matched for each position and the angles for those positions were extracted and compared.

Figure 2. Left Shoulder 45°

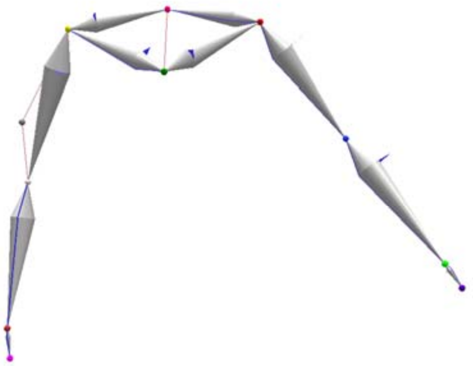


Figure 3. Left Shoulder 90°

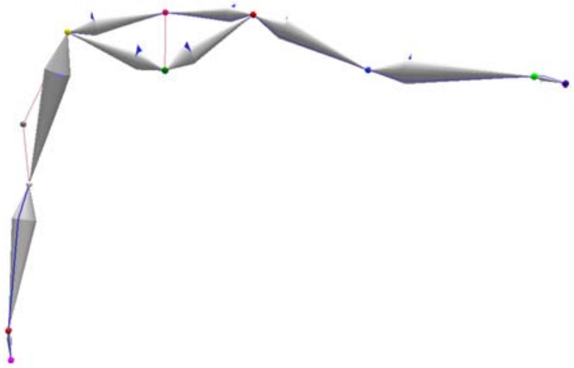


Figure 4. Left Elbow 45°

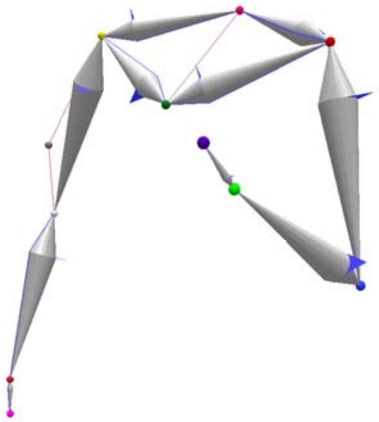
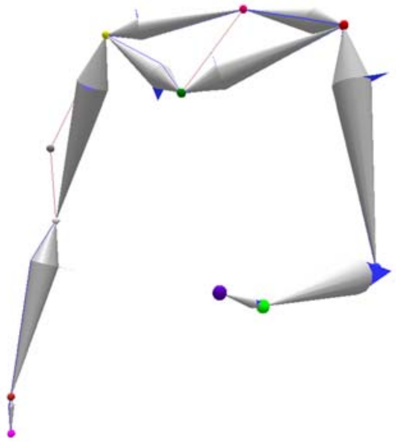


Figure 5. Left Elbow 90°



**note. Figures 2, 3, 4, and 5 do not depict bones, but rather they depict the segments between reflective markers. Although only the left shoulder and arm are illustrated, the right arm and shoulder was also positioned and analyzed.*

Position in space

Two reflective markers were placed 2,518 mm apart on the floor and the markers were used as initial starting and stopping points for the participant. The participant walked from one marker to the other, stopped, turned around, and returned to first marker. Distances between the points and deviation from the initial point of origin and the return to the point of origin was calculated from the X, Y, and Z coordinates for both motion capture methods.

RESULTS

HAND MOTION DISTANCE

The standard unit of measure for the infrared system was millimeters. The electromechanical device records rotations in degrees. The algorithm used to convert the rotations to positions generated coordinates that were converted into measurements in inches. Therefore, distances for the electromechanical device were converted to millimeters prior to statistical analyses.

A paired samples *t*-test was conducted to compare all the distances in hand placement from one peg to another between the infrared motion capture system and the electromechanical motion capture device (22 per hand, 44 for each device). Although the general trends for each hand were somewhat similar, the *t*-test indicated there was a significant difference between the infrared motion capture system and the electromechanical motion capture device ($t(43) = -2.38$, $p = .022$). The mean on the infrared motion capture system was 328.03 mm ($sd = 111.14$ mm) and the mean on the electromechanical motion capture device was 363.77 mm ($sd = 146.19$ mm). *Figures 6* and *7* illustrate the data trends.

Figure 6. Left Hand Trend with Standard Error

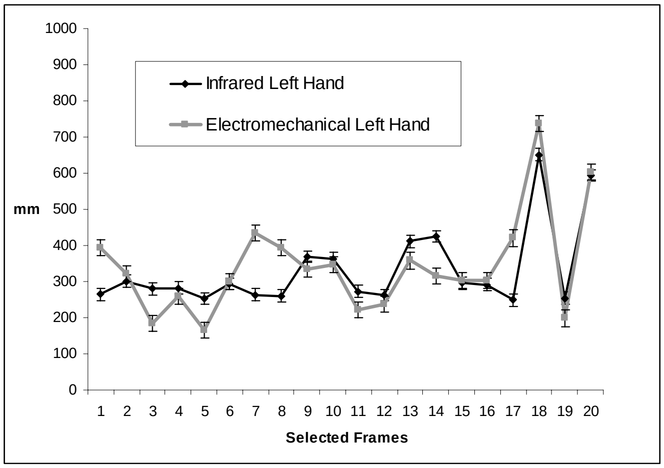


Figure 7. Right Hand Trend with Standard Error

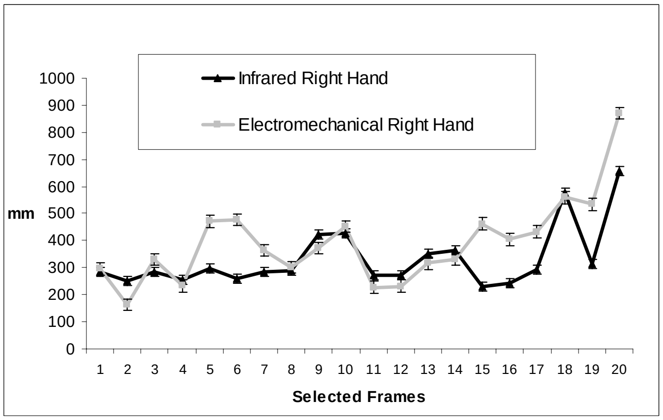


Table 1 contains the distances for each motion capture method by hand for the extracted contact points with the pegs corresponding with the fluid motion depicted in *Figure 1.* Hand Clap 1 is the distance from the initial hand clap to peg 1 as depicted in *Figure 1*, diagram A. Hand Clap 2 is the distance from peg 3 to the ending hand clap as depicted in *Figure 1*, diagram C.

Table 1. Extracted Hand Movement Distances

Hand	Position	Infrared	Mechanical
Left	Hand Clap1	211.92	231.32
	Peg 1 to 2	264.81	392.42
	Peg 2 to 3	301.38	320.96
	Peg 3 to 4	279.83	185.15
	Peg 4 to 5	282.44	258.26
	Peg 5 to 6	252.76	166.07
	Peg 6 to 1	293.71	299.15
	Peg 1 to 2	263.69	435.39
	Peg 2 to 1	260.17	393.70
	Peg 1 to 3	368.55	333.84
	Peg 3 to 1	363.32	348.19
	Peg 1 to 4	272.78	220.99
	Peg 4 to 1	262.74	238.09
	Peg 1 to 5	410.99	357.88
	Peg 5 to 1	424.92	317.02
	Peg 1 to 6	295.41	303.92
	Peg 6 to 1	291.45	302.44
	Peg 1 to 2	248.88	420.45
	Peg 2 to 5	651.42	738.39
	Peg 5 to 6	253.79	198.57
	Peg 6 to 3	593.44	602.48
	Hand Clap2	341.56	532.96
Right	Hand Clap1	169.78	209.41
	Peg 1 to 2	283.02	295.86
	Peg 2 to 3	252.55	162.64
	Peg 3 to 4	285.22	331.30
	Peg 4 to 5	254.90	232.90
	Peg 5 to 6	298.11	471.71
	Peg 6 to 1	261.10	476.02
	Peg 1 to 2	286.30	363.51
	Peg 2 to 1	288.15	300.29
	Peg 1 to 3	421.79	372.74
	Peg 3 to 1	425.11	452.61
	Peg 1 to 4	273.38	227.62
	Peg 4 to 1	270.59	232.16
	Peg 1 to 5	353.16	316.12
	Peg 5 to 1	363.15	331.65
	Peg 1 to 6	231.30	461.33
	Peg 6 to 1	241.58	404.68
	Peg 1 to 2	291.55	432.35
	Peg 2 to 5	578.76	559.30
	Peg 5 to 6	313.09	534.03
	Peg 6 to 3	655.32	870.31
	Hand Clap2	445.27	369.67
Mean		328.03	363.77
Standard Deviation		111.14	146.19

*note. All reported distances are in mm.

Although the movement was complex and involved 22 measures for each hand, because the pegs were placed in a symmetrical configuration, the physical distance between specific groups of pegs was the same. Allowing for subjective hand placement, one would anticipate similar distance measures for selected frames 1 through 8, 11, 12, 15, 16, 17, and 19. Similarly, the distances should be approximately the same for selected frames 9, 10, 13, and 14, while 18 and 20 should be about the same. The electromechanical motion capture device is inconsistent at best and it deviates more than 200 mm from the anticipated distance for some frame measures.

SHOULDER AND ELBOW ANGLES

A paired samples *t*-test was calculated to compare the shoulder angles and the elbow angles generated by the infrared motion capture system to the adjusted shoulder angles (plus 180°) and adjusted elbow angles (plus 90°) extrapolated from the mechanical device potentiometer rotations. The shoulder and elbow adjustments were necessary because the electromechanical device and the infrared motion capture volume had opposite coordinate systems (e.g. one is left handed and the other is right handed. The mean on the infrared motion capture system was 111.02° (*sd* = 36.11°) and the mean on the electromechanical motion capture device was 110.71° (*sd* = 36.89°). No significant differences between the infrared motion capture system and the electromechanical motion capture device were found for the elbow angles and shoulder angles ($t(7) = 0.242$, $p = .816$).

POSITION IN SPACE

Reflective markers were placed 2,518 mm apart on the floor. The participant walked from point A to point B and returned to point A. The distances between the points traversed by the participant were calculated using the X, Y, and Z coordinates. Reflective markers were placed on each foot. All calculations are based on a marker located on the front of the right foot.

The distance for the infrared system from points A to B was 2,526.6 mm and from B to A was 2,519.8 mm. The distance for the electromechanical device from points A to B was 2,344.0 mm and from B to A was 2,451.9 mm. A paired samples *t*-test indicated the distances were not significantly different ($t(1) = 2.295$, $p = .262$). The mean on the infrared motion capture system was 2518.12 mm (*sd* = 2.21 mm) and the mean on the electromechanical motion capture device was 2397.92 mm (*sd* = 76.28 mm).

The distance between the initial X, Y, and Z coordinates at point A (the first time at the point of origin) and the X, Y, and Z coordinates for the return to point A (the second time at the point of origin) for each motion capture method was calculated. The distance for the infrared system was 7.92 mm. The distance for the electromechanical device was 406.19 mm. Unlike the hand movements measured in the current study, a linear movement from one point to another was performed and, thus, a linear relationship can be inferred. Using the distances from point A to B, from point B to A, and point A to A, angles were calculated for each system. The angle for the infrared motion capture system was 0.17° and the angle for the electromechanical device was 9.37°, which represents an absolute difference (or angle of deviation) of 9.20° for the electromechanical device. Because the infrared system was mechanically validated with markers located on the floor, it is assumed most of the difference in the distance between the point of origin measures (from point A to A) for the infrared system could be attributed to the participant's subjective foot placement and differences between the systems for the location near the floor can likely be attributed to error in the electromechanical device.

DISCUSSION

The current study used a third generation electromechanical device. The manufacturer is presently on the sixth generation. The more recent devices may be more accurate than the one used in the current research. The electromechanical device used in the current study had an unsystematic temporal frame rate incongruence. Data was collected several times over a 55-day period in attempts to resolve the temporal frame rate incongruence which was evidenced by capturing too many frames for the length of data collection time. The infrared system used a timestamp based on the internal clock of the computer running the system. The electromechanical device timestamp was based on running time and was calculated from the number of recorded frames. Because the electromechanical device captured more than 120 frames per second (fps) and calculated time at a rate based on 120 fps, it recorded longer samples than were actually collected. In other words, the timestamp did not accurately reflect the actual data collection time. While this variation was not large (from 2.9s to almost 20s), it resulted in 348 to nearly 2,400 extra frames for different trials. Attempted frame rate to time resolutions included trying different sampling rates for both motion capture methods (120 fps each, 60 fps each, 120 fps vs. 60 fps, and 60 fps vs. 120 fps); synchronizing the data for known movements and extrapolating forward, backward, and from the middle of motion capture trials; and systematically removing frames based on recursive mean differences between known points. No method was viable.

The lack of an underlying pattern for the extra frames may have been due to the electromechanical device dropping frames randomly while sampling at a faster rate than reported in the user's manual, the extra frames may have been independently random, or perhaps they resulted from an unknown confound. One possible comparison of the motion capture methods was constructing velocity curves and comparing the curves. Another possible method was calculating the distances for known points of interest and comparing the distances for those specific points. Since velocity curves are time reliant and the timestamp was believed to be inaccurate, we chose to select known points for analyses (i.e., when the hand was at specific locations during the movement). While the solution may not be ideal, it allowed calculating deviations between the motion capture methods that were independent of the timestamps while maintaining a temporal order for limb movements. Although an argument could be made the method is a static posture comparison, it allowed plotting the distances across a series of sequentially ordered sub-movements that comprised a larger more dynamic motion.

The mean deviation of the difference between the angles recorded by the infrared system and those recorded by the electromechanical device was 0.78°, and this difference was not statistically significant. Given the relative agreement between the angles, finding significant differences between the methods of motion capture in hand movement distances and differences in position in space appeared to be somewhat unusual. However, this seemingly unusual finding may have two possible explanations.

First, the rigidity of the electromechanical device's exoskeleton may be a contributing factor to the differences in distance. When the participant twisted his torso to reach for the pegs, the rigidity of the back of the suit may have caused it to pull away from the participant's body. Second, a potentiometer provides a rotation for a single 360° plane. The angles extracted from the potentiometer rotations used for the shoulder analyses came from one potentiometer. The angles used for the elbow analyses were also extracted from one potentiometer. Most importantly they were calculated independent of one another and they were calculated independent of the gyroscope. Hand movement distance calculations relied on a hierarchical composite rotation matrix (the relationships between potentiometers calculated hierarchically). Likewise, location in space also relied on the hierarchical composite rotation matrix.

CONCLUSION

The results of the current study seem to indicate electromechanical motion capture devices are too inaccurate to use for validating digital human models. However, such an assumption may be unwarranted and one should consider the ultimate application of the model. If one needs millimeter accuracy or an absolute location in space, then using another motion capture method is probably best. If one is only interested in joint angles, and distances are secondary, an electromechanical device is acceptable.

Although measurement and angle accuracy constraints may determine which motion capture method is appropriate, these constraints may not be a concern for many digital human model applications. For example, the tables for the National Institute for Occupational Safety and Health (NIOSH) Lifting Equation [10], Rapid Upper Limb Assessment (RULA) [11], Rapid Entire Body Assessment (REBA) [12], and Snook and Ciriello's Liberty Mutual equations [13] for lifting, pushing, and pulling allow for considerable distance measurement error. The tables are "look-up tables" and each table does not use an exact measure of distance, but rather a range of distances. Depending on the table and the task, ranges vary from about 50 mm to 254 mm. These ranges are broad enough that additional measurement error from an electromechanical device may be irrelevant or have little, to no, impact.

Determining which type of motion capture method to use can be made based on the researcher's needs. If joint angles are the primary interest and distance is unimportant, an electromechanical device may be adequate. If location and precise distances are desired, an electromechanical motion capture device may be inadequate. However, other factors, such as space, time, economic constraints, and environmental conditions may require trading off the most reliable method of measurement in order to collect data.

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REFERENCES

1. Sturman, D. *A Brief History of Motion Capture for Computer Character Animation: Character Motion Systems,* **Siggraph 94, Course 9.**
2. Weber W, Weber E: **Mechanik der menschlichen Gehwerkzeuge.** *Göttingen: Dieterich* 1836.
3. Münderman, L, Corazza S, Andriacchi T: **The evolution of methods for the capture of human movement leading to markerless motion capture for biomechanical applications.** *J Neuroengineering Rehabil.* 3:1:6. 2006.
4. Marey E: **Animal Mechanism: A Treatise on Terrestrial and Aerial Locomotion.** London: Henry S. King & Co.; 1874.
5. Muybridge E: **Animal locomotion.** Philadelphia: J.B. Lippincott Company; 1887.
6. Herda, P. Fua, R. Plänkers, R. Boulic and D. Thalmann. **Using skeleton-based tracking to increase the reliability of optical motion capture,** *Human Movement Science 20.* 313–341, 2001.
7. **Inition: Optical guide.** Retrieved on April 16, 2007from the World Wide Web at http://www.inition.co.uk/inition/guide_19.htm on April 16, 2007.
8. Francis, J. Personal communication. **MotionAnalysis**, April 16, 2007.
9. **Inition: The blurb.** Retrieved on April 16, 2007from the World Wide Web at http://www.inition.com/inition/product.php?URL_=product_mocaptrack_animazoo_gypsygyro_18&SubCatID_=0 on April 16, 2007.

10. Waters, T, Putz-Anderson, V, & Garg, A. **Applications Manual For The Revised NIOSH Lifting Equation.** U.S. Department of Health and Human Services. DHHS (NIOSH) Publication No. 94-110, 1994.
11. McAtamney, L, & Corlett, E. **RULA: A survey method for the investigation of work-related upper limb disorders.** *Applied Ergonomics. 24(2).* 91-99, 1993.
12. Hignett, S., & McAtamney, L. Rapid Entire Body Assessment: REBA. *Applied Ergonomics, 31,* 201-205, 2000.
13. Snook, S. H. and Ciriello, V. M. The Design of Manual Handling Tasks: Revised Tables of Maximum Acceptable Weights and Forces. *Ergonomics, 34:9.* 1197-1213, 199l.

AUTHORS' NOTE

We have collected motion capture data on assembly lines, during dynamic target acquisition and live gunfire, in driving simulators, during lifting tasks, during automobile ingress and egress, during human-machine interactions, and during a variety of natural tasks. We have collected data in real-world environments as well as in a motion capture studio and we are currently collecting data to be used to validate a digital human model.

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