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14. ABSTRACT
The objective of our study is to produce a computer-based Advanced Prosthetic Gait Training Tool to aid in the training of clinicians at military treatment facilities providing care for wounded service members. In Year 1 of the effort, significant work was completed at the University of Iowa Center for Computer-Aided Design (CCAD), the University of Iowa Orthopedic Gait Analysis Laboratory (OGAL), and the Military Performance Laboratory (MPL). A representative set of motion capture sequences was provided by MPL to CCAD and OGAL. CCAD's work focused on imposing these sequences on the Santos™ digital human avatar. An initial user interface for the training application was also developed. During the current year, the user interface was significantly enhanced. In addition, various mechanisms of training clinicians were tested by the team at OGAL and VSR. Finally, motion capture data transfer protocol was tested between the teams at OGAL and VSR. During the next year, data collection is expected to be complete at the University of Iowa's OGAL.

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Advanced Prosthetic Gait Training Tool

Introduction

The objective of our study is to produce a computer-based Advanced Prosthetic Gait Training Tool to aid in professional development for clinicians and prosthetists at military treatment facilities providing care for wounded service members. The effort will ultimately provide practitioners at all clinics and hospitals with access to advanced, computer-based gait analysis tools that are currently available at only a few state-of-the-art gait laboratories. The tool will aid in the training of service providers, ultimately improving the level of care they provide to wounded veterans.

Due to the wide variety of injuries suffered by military personnel and the wide range of medical interventions employed to improve the standard of living for patients, it is very challenging to expose medical practitioners to a comprehensive set of human subjects to support their training in gait analysis. Under this effort, an extensive set of archived motion capture data representing gait patterns for wounded service members with varying challenges will be harvested from the Military Performance Laboratory at the Center for the Intrepid at Brooke Army Medical Center in San Antonio.

To ensure confidentiality for these service members, the gait patterns will be imposed on a digital human model, referred to as Santos™. This computer-based model provides additional benefit to trainees, allowing for the repeated virtual playback of motion capture sequences that can be viewed from any angle. The trainees will enter their assessments of observed gait deviations, which will be scored against standard measures prepared by experts in the field. Based on the accuracy of the trainees' responses, the system will provide remediation. When fully developed, this system will provide a comprehensive training experience, allowing practitioners to benefit from a broad array of patient data previously collected by the US Army, thus bridging a critical gap in current medical training practices. The system will be developed to accommodate additional sequences captured over time, thus offering an extensible, distributable, and sustainable training library.

In Year 1 of the effort, significant work was completed at the University of Iowa Center for Computer-Aided Design (CCAD), the University of Iowa Orthopedic Gait Analysis Laboratory (OGAL), and the Military Performance Laboratory (MPL). A representative set of motion capture sequences was provided by MPL to CCAD and OGAL. CCAD's work focused on imposing these sequences on the Santos digital human avatar. An initial user interface for the training application was also developed. These data were then provided to researchers from OGAL and MPL to support an assessment of the ability of trained clinicians to observe and accurately identify gait deviations in the target environment. Researchers at OGAL also embarked on a program to develop a web-based questionnaire using the Santos software. This questionnaire will be sent to experts in the field of gait analysis. The primary goal of the questionnaire is to identify the sensitivity of gait experts to detect variations in gait for different severity levels of the patients. In addition, the differences in ability to detect variations in gait conditions for skinned avatar vs. line-skeletal avatar, concurrent (side-by-side) image representation vs. consecutive (one after the other) image representation, and image vs. movie representation was also studied. The information gathered from this approach will be used to identify a set of gait profiles and to develop the training and evaluation questionnaire.

During Year 1 of Phase 2 effort, the initial interface was improved further with feedback from gait experts at OGAL to incorporate tutorial options to best train a new clinical student in gait deviations. For most of Year 1 of phase 2, MPL was responding to queries and waiting for IRB approval to collect the data necessary to go into the software. However, OGAL members created a couple preliminary tutorials using dummy data to try out various ideas in training. These tutorials served as reference for VSR to incorporate the interface changes and develop additional capabilities to enhance learner interaction with the software. In the sections below, these training ideas and the development of the tutorial are discussed.

During Year 2 (First no-cost extension) of the Phase 2 effort, substantial improvements in the interface were made while waiting for MPL to collect the data. However, due to long delays in getting IRB, MPL could not schedule resources during the year 2014 to allocate to this project. Near August 2014, it was decided that additional data will be collected at the University of Iowa and not at MPL due to shortage of manpower at MPL. Hence, a no-cost extension was applied in August 2014 while the process of IRB was also started. Below is the current progress report on the status and developments of the program during the year 2014.

The current base effort built upon the Phase 1 demonstration of the feasibility of developing a curriculum centered around motion-capture data collected at MPL within the Santos software. The three main components of the project are: 1) motion capture investigations; 2) gait deviation ratings; and 3) software design. The team was able to progress on two of these three main components: the gait deviation ratings and the software design.

Motion Capture Investigation:

Data were obtained from the Gait Lab, using different marker protocols, for proof of concept in translating the new marker-protocol of the gait data to the Santos model in a consistent manner. Based on the provided gait data, some joint center profiles were provided and other were generated inside Virtual 3D using the new marker protocol. Promising results have been seen to increase the timeliness and efficiency of data transfer from the motion capture inside Virtual 3D space to the Santos environment, with more potential improvement in the near future.

Methodology outline

Human gait test data under different protocols were obtained for trans-tibial amputee. The following steps were taken to translate the data from motion capture to the Santos model (see Figure 1).

1. Visual 3D model was used at the Gait Lab to generate the required markers and to estimate some joint-center locations of the different body segments (Figure 1a).

2. Addition Visual 3D virtual points were created at the 3DBMRL lab and were exported for additional joint centers relative to the Santos skeleton (Figure 1b).
3. Link lengths between segments were calculated for input into the Santos skeleton (Figure 1c).
4. An in-house inverse kinematic software was used to predict joint angles of different segments that were used subsequently as input motion file for Santos animation (Figure 1d).

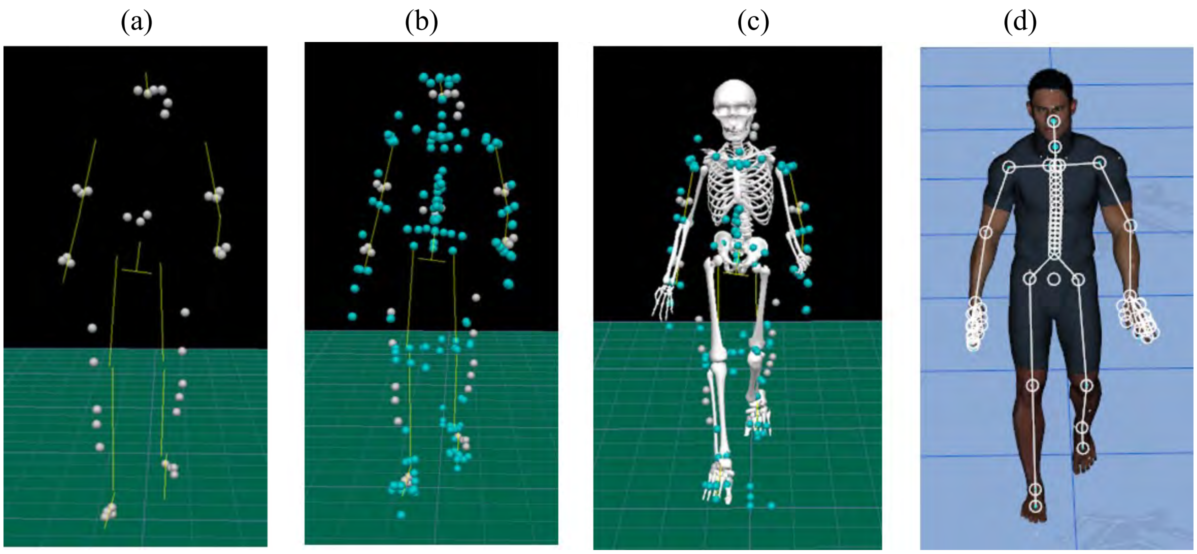
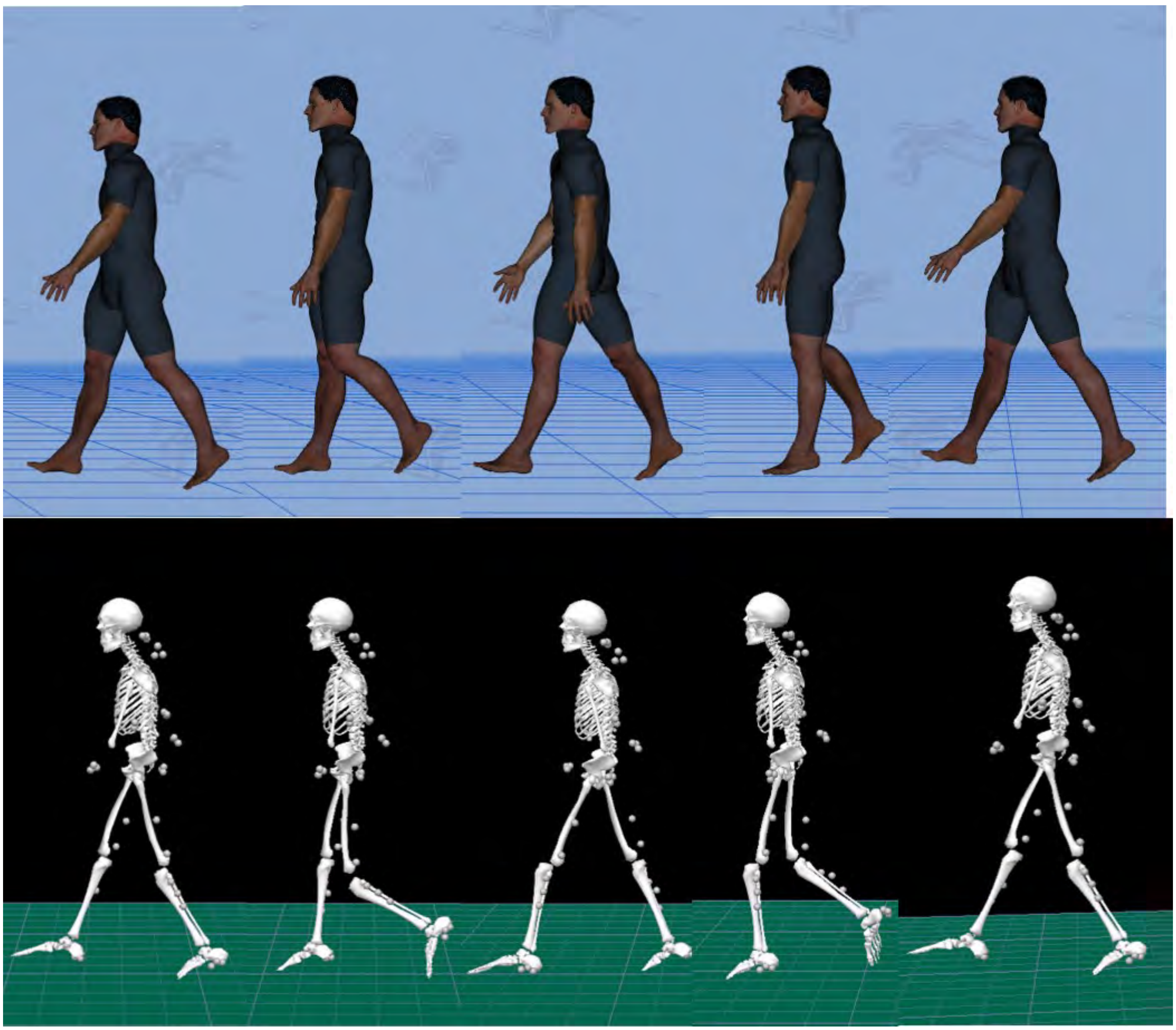


Figure 1 - The flow from motion capture data collection to animation in Santos. (a) motion capture markers only inside Virtual 3D, (b) landmarks created in the body based on motion capture markers inside Virtual 3D, (c) skeleton added in Visual 3D model to calculate different segment lengths, and (d) joint centers exported to Santos for animation

Table 1. Santos joint center locations required to recreate motion capture data from in-house predictive dynamics optimization code

NAME	LOCATION
Spine1	Base of the spine near L5 spinous process
Spine2	Proportional distance up spine near T12 spinous process
Spine3	Proportional distance up spine near T10 spinous process
Spine4	Proportional distance up spine near T7 spinous process
Spine_Rigid	Intersection of spine and the point between the shoulder joints
LowNeck	Base of the neck near C7 spinous process
UpperNeck	Top of the neck near C1 spinous process
LCLAV, RCLAV	Approximately one-fourth distance between manubrium and acromion
LSHO, RSHO	Shoulder joint center, slightly inferior of acromion
LELB, RELB	Elbow joint center, between lateral and medial epicondyles of humerus
LWRST, RWRST	Wrist joint center, between radial process and ulnar styloid process
LFIN, RFIN	On index finger near 1st metacarpal head
LHANDB, RHANDB	Distal end of middle phalange and used as end effector
Lhip, Rhip	Hip joint center, proportioned from RASIS, LASIS, RPSIS & LPSIS

LKNEE, RKNEE	Knee joint center, between lateral and medial condyles of femur
LANKLE, RANKLE	Ankle joint center, between lateral malleolus of fibula and medial malleolus of tibia
LTOE, RTOE	Between midpoint of 5th metatarsal and head of 1st metatarsal and used as end effector
MidHead	Center of head rotation at the C0 occipital joint
Head_Right	Outside point of head directly lateral of MidHead
RBAK	Medial border of the scapula on the level of T3, approximately midpoint between T7 spinous process and right shoulder joint



RHS LTO LHS RTO RHS

Joint center protocol

The Visual 3D model was used for generating different anatomical joint center locations. Additional joint center locations and virtual markers were created to adhere to the Santos model. The Santos model requires the following joint center protocol as seen in Table 1. Based upon the data received from the Gait Lab, the following joint centers were estimated inside Visual 3D model:

Results of simulation:

Figure 2 shows critical key frames of the gait cycle using Santos (Figure 2a) and Virtual 3D (Figure 2b).

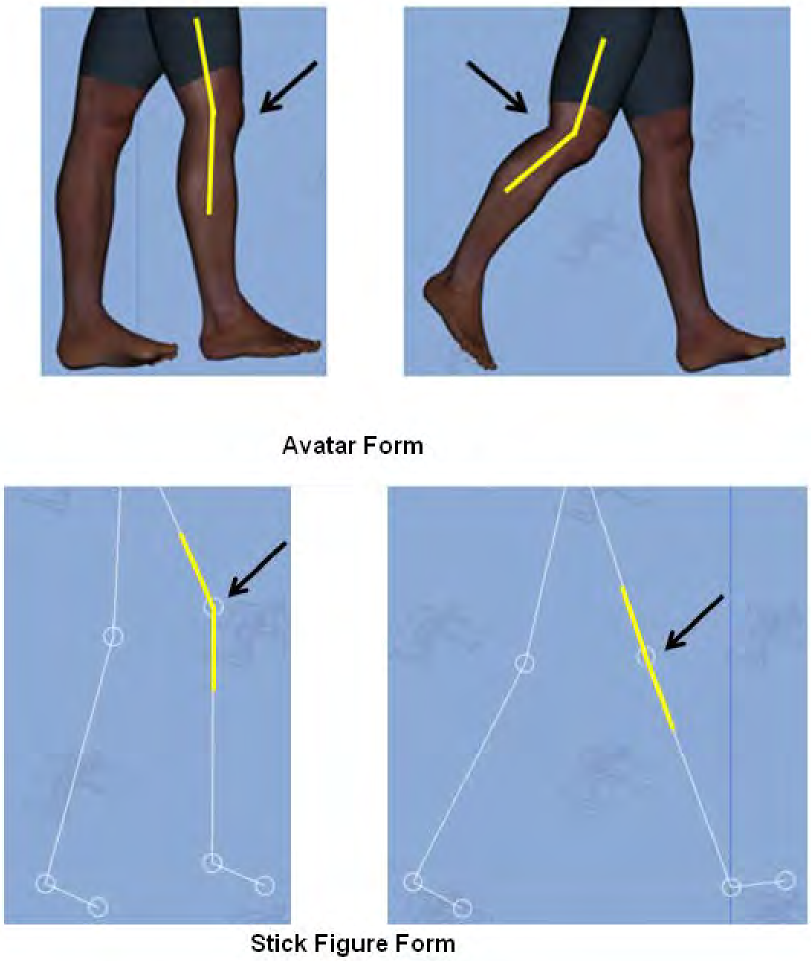


Figure 1: Examples of the type of visual comparisons that the observer was asked to judge.

Gait Deviation Ratings

We have developed an assessment to examine general issues related to the ability of the user to observe differences in the walking pattern. We have created a module to assess Visual Sensitivity - Module 1. We have also generated two modules to train individuals to distinguish gait deviations: Observational Gait Analysis : Module 1 - Trunk Motion and Observational Gait Analysis : Module 2 - Lower Limb Motion.

Visual Sensitivity (VS) – Module 1

[Link to the module: https://uiowa.qualtrics.com/SE/?SID=SV_eR5vVCSaSKMASax]

The goal of the first VS Module is to assess the sensitivity of observers in visually detecting differences in static images of the knee joint, represented at various times during the walking cycle. To accomplish this, two images of the knee are presented with approximately 0, 5, or 10 degrees of difference. A secondary goal of this module is to determine if the ability to detect differences was affected by the image presentation. To accomplish this, both stick figure representations and avatar representations were used. Figure 1 below shows an example of the images.

The users were asked to rate their confidence in judging the differences between the two modules (Figure 2).

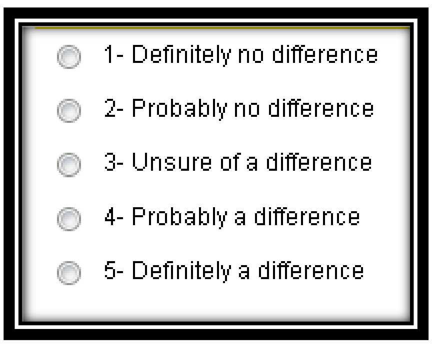


Figure 2: Scoring system used by observers to represent their ability to detect differences between the two images.

Data from 20 practicing physical therapist has been collected and is currently being analyzed.

Evaluation using Visual Sensitivity (VS) – Module 1

We have used the Visual Assessment Module to determine the ability of clinicians to visually detect differences in static images of the knee joint. Thirty-five practicing Physical Therapists, volunteered and provided Informed Consent. They were provided a link to the online evaluation. Each Physical Therapist (reader) evaluated 30 pairs of static images with respect to joint angles obtained from walking data. In 10 of the pairs, the difference of the angles was 0 degrees; in 10 pairs it was 5 degrees; and in 10 pairs it was 10 degrees. Each reader rated their confidence of a difference on an ordinal 1 (definitely no difference) to 5 (definitely a difference) scale. Each reader's accuracy was considered by the probability that, if presented with an equal-angle cluster and an unequal-angle cluster, he or she would correctly identify the unequal-angle cluster, i.e., would correctly discriminate between the two types of clusters. This probability is estimated by the empirical area under the *Receiver Operating Characteristic* (ROC) curve, as denoted by AUC.

The empirical AUC can be computed as the proportion of all possible pairs of clusters, with each pair containing one equal-angle and one unequal-angle cluster, such that the reader rated the unequal-cluster pair higher than the equal-angle cluster (on the confidence-of-a-difference-in-angles rating scale). An AUC value of .5 indicates no discrimination (i.e., discrimination ability same as random guessing) while AUC = 1 indicates perfect discrimination. AUC's were computed for the entire sample of clusters and for two subsets: subset 1 contains the 10 equal-angle clusters and the 10 (angle diff = 10 degrees) unequal-angle clusters; subset 2 contains the 10 equal-angle clusters and the 10 (angle diff = 5 degrees) unequal-angle clusters.

The descriptive statistics for the AUCs computed from all of the data and from subsets 1 and 2 are presented in Table 1. Not surprisingly, we see that the highest AUC, averaged across readers, occurs for subset 1, where all of the unequal-angle clusters have angles differing by 10 degrees. For subset 1, AUC = 0 .61 (CI: 0.58 – 0.63). Thus, the estimate of the average reader's accuracy was .61, meaning readers showed significant discrimination ability.

For subset 2, where all of the unequal-angle clusters have angles differing by 5 degrees, AUC = 0.48 (95% CI: 0.46 – 0.50). Since AUC = .50 represents random guessing, we cannot conclude that readers showed significant discrimination ability.

The analysis results indicate that reader can discriminate between a pair of images with the same joint angle and a pair of images having joint angles that differ by 10 degrees with 61% accuracy. This was considered low-to-moderate degree of accuracy. On the other hand, there was no evidence suggesting that readers can discriminate better than chance when the difference is 5 degrees. None of the four covariates showed a significant association with discrimination ability.

This study provides baseline information on the capability of observers to detect differences in joint angles using static images. This information will be used in module development to help establish a minimal detectable difference that observers can judge prior to training.

Table 1. Descriptive statistics for AUCs.

Cluster Subset	N (No. of readers)	Mean	StdDev	95% CI_Low	95% CI_high	min	max
All	35	0.54	0.06	0.51	0.56	0.37	0.66
1	35	0.61	0.08	0.58	0.63	0.36	0.72
2	35	0.48	0.06	0.46	0.50	0.35	0.61

Notes: Cluster subset "All" contains all of the image clusters. Image subset 1 does not include image clusters where the image angles differ by 5 degrees. Image subset 2 does not include image clusters where the image angles differ by 10 degrees.

Observational Gait Analysis Modules – Phase I

A series of OGA Modules for Phase I are being generated with the goal of honing the observational skills of the users. Modules in this phase will focus on the ability of the user to discriminate between a more ideal walking pattern and non-specific gait deviation. The approach taken is to segment the process by focusing attention on the motion of the trunk and the motion of one lower limb before trying to examine total body motion. The body representations for these initial modules are stick figures.

Observational Gait Analysis (OGA) Module 1: - Trunk Module

[Link to this module: https://uiowa.qualtrics.com/SE/?SID=SV_7P0WyWVTlILSHwF]

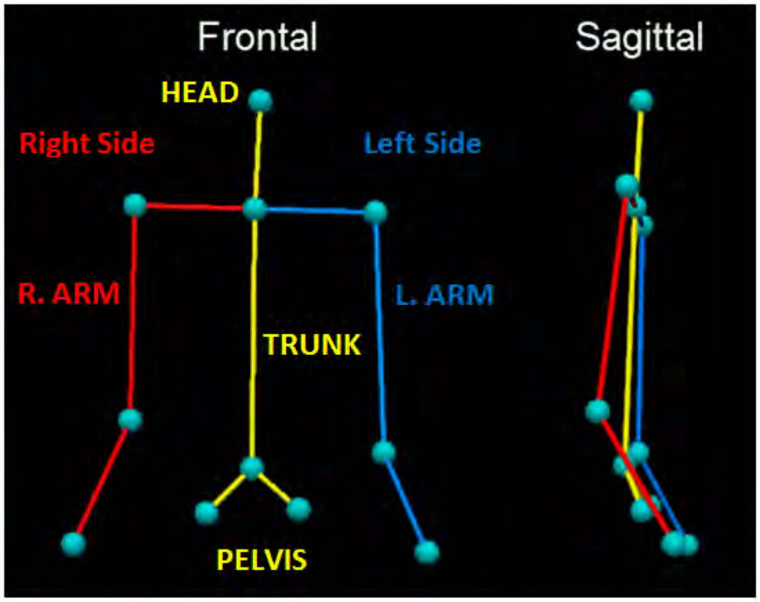


Figure 3: Frontal and sagittal plane stick figure representations of the trunk, head, and arms.

This module is focused on distinguishing deviations in movements of the head and trunk during walking. The observer is asked to consider stick figure representations of motions of the head, arms, and trunk (HAT) when viewed from the front (frontal plane) and the side (sagittal plane) relative to what is considered a more ideal pattern of motion (Figure 3).

The observer is shown a video clip representing a normal movement pattern of the HAT and then asked to judge potential deviations in the movement of the HAT.

- ○ Close to Ideal
- ○ Apparent Deviations
- ○ Not Ideal, but cannot distinguish the specific deviations

Trunk Motion:

Items
R. Side
L. Side
L. & R. Side
Front
Back
Front & Back

Figure 4: If the user identifies that there is a deviation, then they are asked to judge the nature of the deviation.

Figure 5: Once the observer has decided if and what the deviations in HAT motion are, visual feedback is provided showing the pattern of motion relative to the vertical orientation and relative to a more ideal pattern.

Observers are then provided with feedback showing the pattern of motion relative to a vertical axis and comparing the current pattern to a more ideal pattern (Figure 5). Text is also provided that identifies the more obvious deviations.

Thus far, we have distributed a draft of this module to 15 students in an effort to get feedback on the organization and presentation of the material.

OGA Module 2: Single Lower Limb Module

[Link to this module: https://uiowa.qualtrics.com/SE/?SID=SV_88Fl8NcO4ytXxk1]

This module is focused on distinguishing deviations in movement of the lower limb during walking. The observer is asked to consider stick figure representations of motions of the lower limb when viewed from the front (frontal plane) and the side (sagittal plane) relative to what is considered a more ideal pattern of motion (Figure 6).

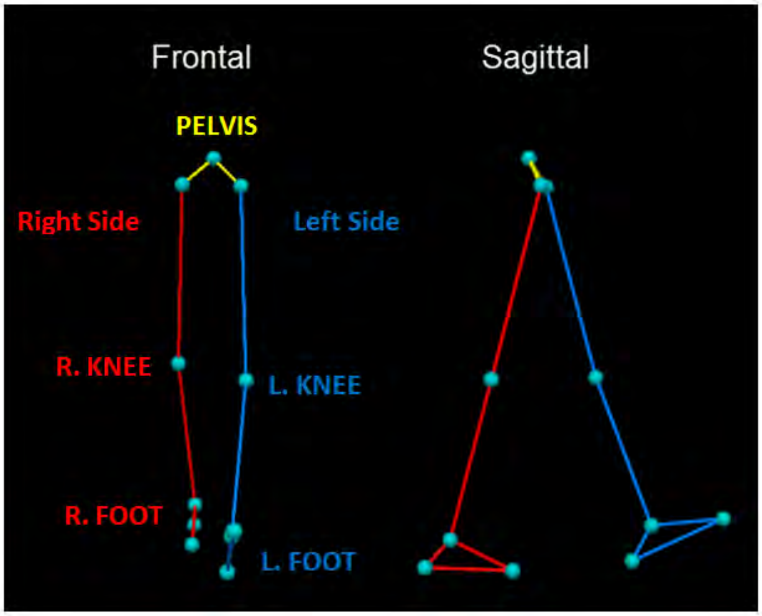


Figure 6: The lower limb module represents the movement of both lower limbs during walking from the frontal and sagittal perspectives.

Observers are asked to focus on four critical times during the walking cycle and to detect differences from the ideal (Figure 7).

Observers will initially be asked to determine if they perceive a deviation. If they have identified a deviant pattern, they will be asked to attribute the deviation to specific issues in the frontal and sagittal planes (Figures 8 & 9).

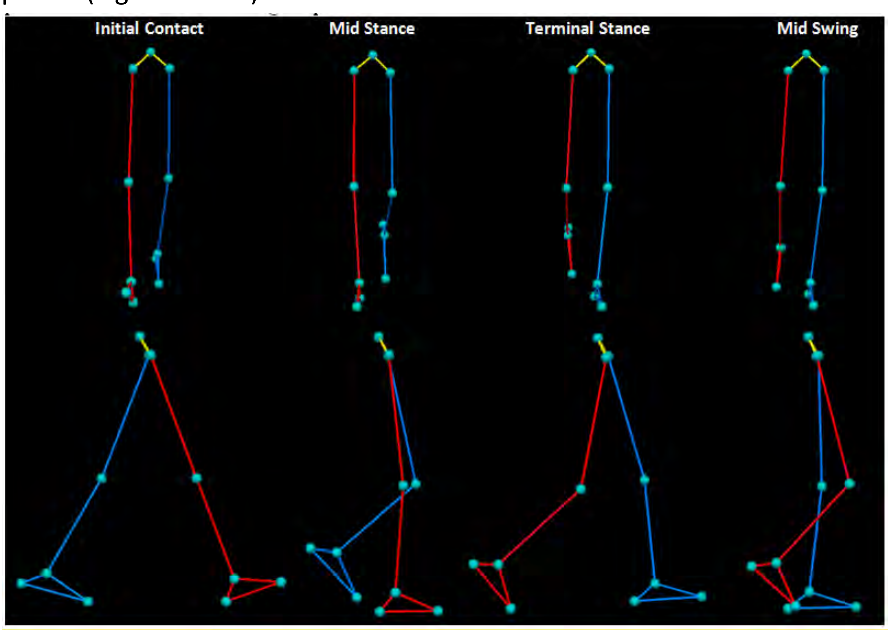
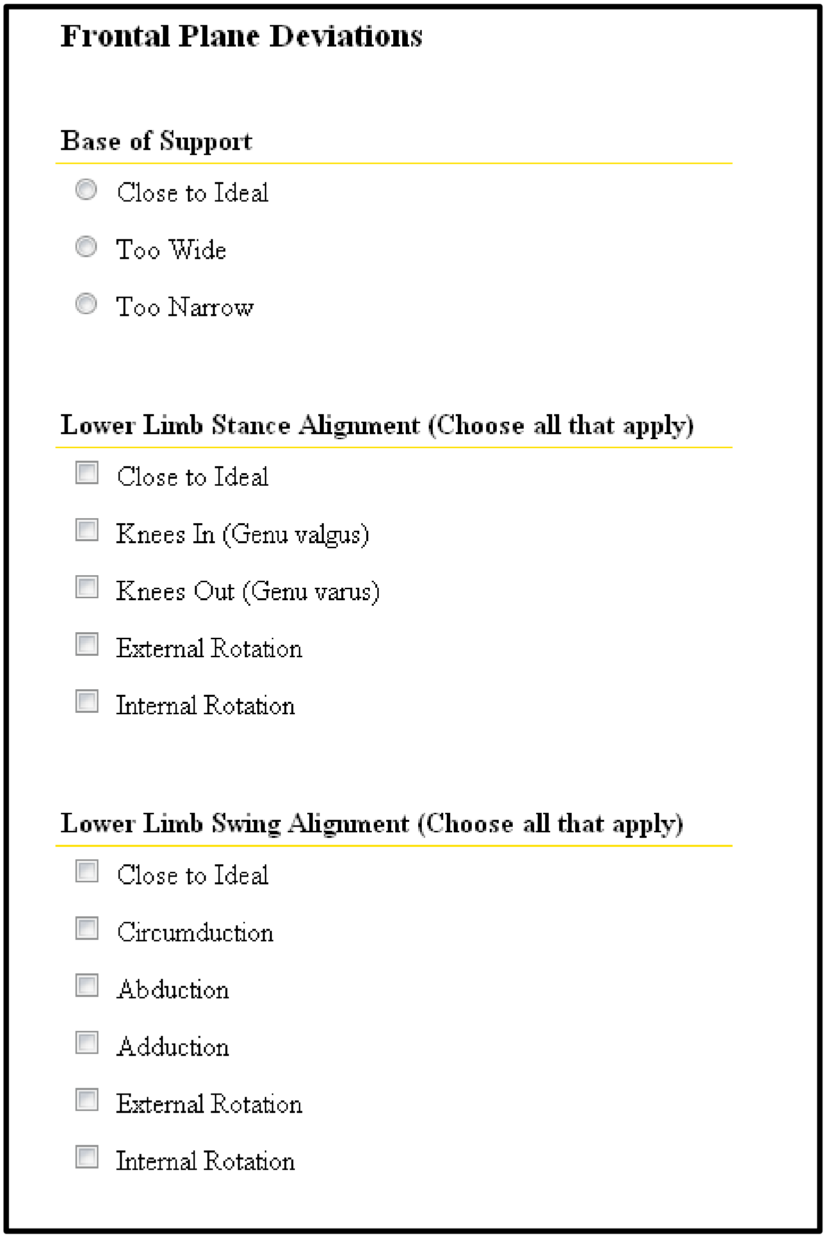


Figure 7: The position of the lower limb at four critical times during the walking cycle as seen from two perspectives.

Once the user has registered an assessment, visual and text feedback is provided that helps to identify the more obvious deviations (Figure 10).

This module has been distributed to project personnel for feedback. We are currently revising it and plan to send it out for additional feedback.



Frontal Plane Deviations

Base of Support

- ○ Close to Ideal
- ○ Too Wide
- ○ Too Narrow

Lower Limb Stance Alignment (Choose all that apply)

- ☐ Close to Ideal
- ☐ Knees In (Genu valgus)
- ☐ Knees Out (Genu varus)
- ☐ External Rotation
- ☐ Internal Rotation

Lower Limb Swing Alignment (Choose all that apply)

- ☐ Close to Ideal
- ☐ Circumduction
- ☐ Abduction
- ☐ Adduction
- ☐ External Rotation
- ☐ Internal Rotation

Figure 8: Possible lower limb deviations observed in the frontal plane.

OGA Module 3: Pre/Post Testing Module

We have created an additional**, Pre/Post Testing Module**, that uses video clips of deviant walking patterns, similar to what clinicians may see in a clinical setting, to assess the observer's ability to detect gait deviation. The intent of this module is to have a mechanism for performing Pre/Post Testing that will allow us to judge the effectiveness of the training modules.

Sagittal Plane Deviations

Joint Range of Motion around Initial Contact

	Increased Flexion/Decreased Extension	Decreased Flexion/Increased Extension	Close to Ideal
Hip	○	○	○
Knee	○	○	○
Ankle (Dorsiflexion/Plantarflexion)	○	○	○

Joint Range of Motion around Mid Stance

	Increased Flexion/Decreased Extension	Decreased Flexion/Increased Extension	Close to Ideal
Hip	○	○	○
Knee	○	○	○
Ankle (Dorsiflexion/Plantarflexion)	○	○	○

Joint Range of Motion around Terminal Stance

	Increased Flexion/Decreased Extension	Decreased Flexion/Increased Extension	Close to Ideal
Hip	○	○	○
Knee	○	○	○
Ankle (Dorsiflexion/Plantarflexion)	○	○	○

Figure 9: Possible lower limb deviations observed in the sagittal plane.

The module incorporates six video clips, selected from a library of recordings, showing the frontal and sagittal views for one gait cycle. Twenty critical indices, taken from existing gait assessment tools (Edinburgh Visual Gait Score, the Gait Assessment and Intervention Tool (G.A.I.T.), and the Ranchos Los

Amigos Gait Assessment) were used to judge the gait patterns. These indices focused on range of motion issues at the trunk, hip, knee, and ankle at critical stages in the gait cycle. A slider scale is used to express the direction and severity of these twenty indices based on the observer's recollection of what is ideal.

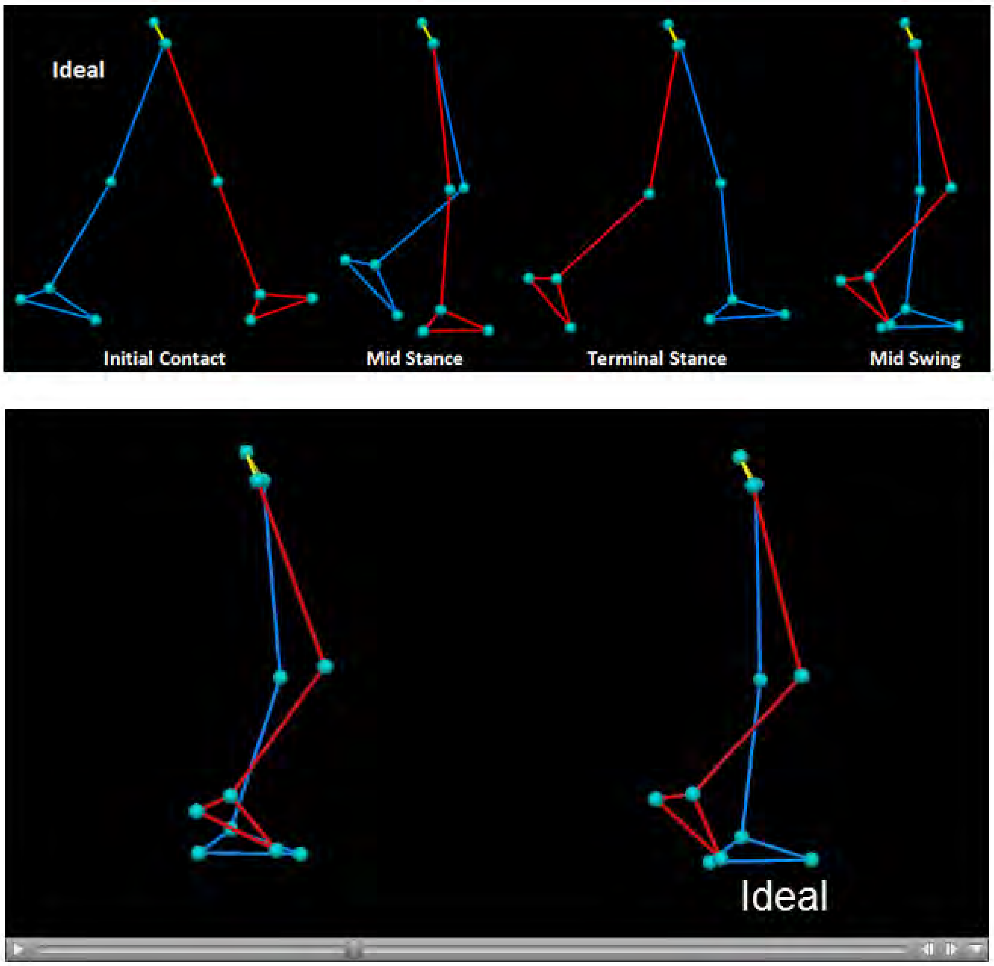
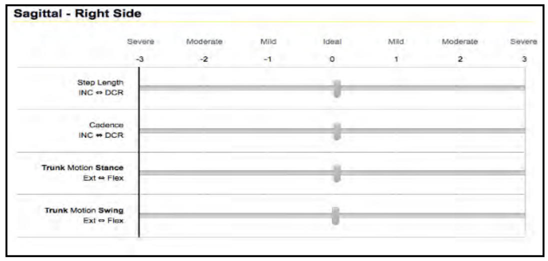


Figure 10: Visual feedback provides information on the ideal pattern at specific time in the gait cycle, as well as a side-by-side comparison of the gait pattern relative to the ideal pattern.

These walking patterns were also assessed during an instrumented gait analysis using conventional 3D motion analysis. The 20 indices used in the assessment were quantified and compared relative to a normal dataset. The magnitude of the deviation from normal for each measure was expressed in terms of the standard deviation (SD) within a normal dataset (Perry & Burnfield, 2010).

We have done limited testing on this module to determine the sensitivity and validity of this evaluation. Twenty student volunteers from each of the current University of Iowa DPT1 and DPT2 classes were solicited as subjects. A total of 10 students (5 from each class) responded. Three of the 10 students completed the module a second time, with a minimum of four days in between, to assess the intra-rater reliability.

Temporal Spatial- Coronal	Lower Limb- Sagittal
Base of support	Hip TS
Limb alignment swing	Hip Sw
Trunk motion stance	Knee IC
Trunk motion swing	Knee MSt
Pelvic Swing	Knee PSw
	Knee MSw
Temporal Spatial- Sagittal	Knee TSw
Step length	Ankle IC
Cadence	Ankle PSw
Trunk motion stance	Ankle MSw
Trunk motion swing	Ankle TSw



To determine if participants were able to detect a gait deviation, we analyzed the data as a frequency of "yes" (non-zero) vs "no" (zero) responses relative to the severity of the gait deviation. We required the slider to be moved +/- 0.25 on a scale of +/- 3 away from zero in order to be considered a "yes" response. Gait deviations were divided based on the SD (.5-1.0; 1.1-2.0; 2.1-3.0; greater than 3.1). To determine if participants identify the correct direction and severity of the deviation we looked at the responses at each joint. Scatter plots were created to see if the correct gait deviation was chosen and if the severity was consistent with the deviation from normative measures. Reliability was assessed using a correlation analysis of the data.

When the deviation from normal values was less than 3 SD, subjects were able to identify the existence of a deviation 40% of the time. When the deviation was greater than 3 SD, subjects were able to identify the existence of a deviation 51% of the time, an 11% increase.
The strongest associations between observers scoring and the measured deviation from normal was seen at the ankle, knee and trunk were respective R-Squared values were .26, .23, .82. It is worth noting that the range of responses on the sliding scale was generally between +/- 2. These results suggest our tool is sensitive to not only the detection of deviations, but also the assessment of the severity of the deviation.

Reliability analysis determined an intra-rater reliability for the three students who repeated the module a second time of .44. Our reliability scores are lower than those in existing literature assessing Observational Gait Analysis tools. Based on subjective feedback from the testers, the intra-rater reliability of the tool may have been affected by the time required to utilize the tool and potential difficulties navigating the tool.

Based on our findings, this tool shows promise in being utilized to assess a clinician's baseline Observational Gait Analysis abilities and has the potential to measure improvements in Observational Gait Analysis abilities after a training interventions. While the tool has been shown to be sensitive enough to pick up on potential improvements that may result from training, there is still a need to further modify this tool. Logistical issues, related to the user interface, affected the operating ease and time required to complete this module. We believe these issues are critical to address in order to improve the validity of this evaluation module by keeping the subject's attention and keeping them motivated.

Goals

We are in the process of integrating these modules into the environment generated by CCAD. In Phase II, we will develop the training modules specific to the gait patterns of individuals with amputations, now that gait data collected has shifted to OGAL. Since the biomechanical models created by OGAL are somewhat different from MPL, we are in the process of interfacing with VSR to allow these models to be represented in SANTOS. Thus far we have invested time in getting the interface to work and we are currently ironing out some of the finer details of the model interface.

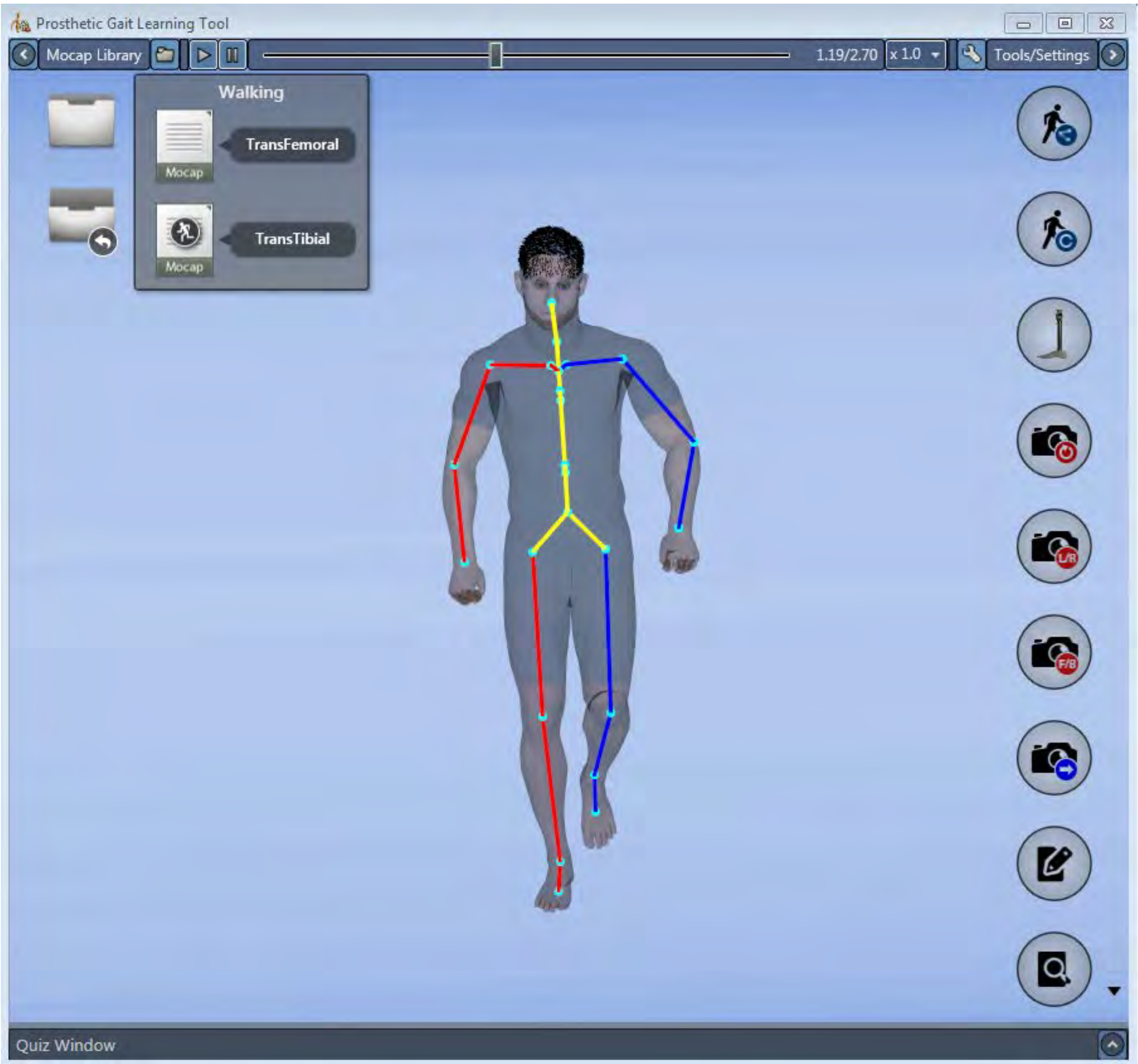


Figure 11: The Prosthetic Gait software after a MoCap file has been selected from the slide-out library. Additional tools have also been brought into view using the arrow on the main toolbar, which also includes access to the playback tools.

As the modules mature, we will continue to test the content and logistics to ensure that these modules are not only effective for testing and training, but have user friendly interfaces that will allow them to be accepted and accurate.

Prosthetic Gait Software

The functionality and visual appeal of the Prosthetic Gait software has improved significantly over the past year. The layout and usage of the software has been developed into a more intuitive and user-friendly format, and the accompanying quiz window has been remodeled to feature many new capabilities.

With the default startup of Prosthetic Gait, the Santos avatar is displayed in the center of the screen with 50% opacity and his color-coded line body skeleton shown. The avatar is initially loaded with a control MoCap file. The main toolbar, including access to the slide-out MoCap library, the playback tools, and the slide-out additional tools/settings, is positioned at the top of the screen. Minimized by default, the quiz window makes up the bottom of the screen.

By clicking the MoCap library arrow in the top left corner, folders containing MoCap files slide into view. Tooltips containing each folder's category can be seen by hovering the mouse over each folder. The folders are currently organized into three categories: Control, Lower Body, and Upper Body. Opening a folder displays either the sub-folders inside of each category, if any exist, or the motion capture files. For instance, if the Lower Body folder is clicked, two more folders (Running and Walking) pop up. Selecting either of these folders brings up the corresponding MoCap files associated with lower body gait issues. The avatar is loaded with the appropriate data upon clicking a specific motion file. After selecting a new MoCap file, an icon is displayed on the respective file to enhance ease of user navigation within the folders, as seen in Figure 11.

MoCap files can be played on the avatar through the use of the playback tools. The toolbar consists of a play button, pause button, playback slider, running time, and a play speed dropdown button. The playback slider allows for the user to manually select a frame of motion, and the time updates with sliding as well. The playback speed dropdown can be used to view motion at various speeds (x2.0, x1.0, x0.75, x0.5, x0.25).

Additional tools and settings can also slide in and out of view using the arrow in the top right corner. Tooltips display the capabilities of the buttons, which include: Show/Hide Skeleton, Show/Hide Control Avatar, Show/Hide Prosthetic, Free Camera View, Left/Right View, Front/Back View, Camera Follow On/Off, MoCap Offsets, and Lower/Upper Zoom. Clicking the Show/Hide Skeleton button toggles between an almost transparent avatar with line skeleton, a fully opaque avatar with no line skeleton, and the default 50% opacity avatar with line skeleton. The color scheme of the line skeleton has been modified to match the online quiz developed by OGAL. The Show/Hide Control Avatar button will add or remove a fully opaque avatar with no line skeleton next to the current avatar. The avatar produced by this button will always play the control MoCap file. The user can toggle between the regular Santos avatar and a new avatar featuring a prosthetic leg by clicking the Show/Hide Prosthetic button, shown below in Figure 12. The line skeleton and all other functionalities can still be applied to the avatar with the prosthetic leg. Free Camera View, meaning the user is able to click and drag the camera around, can be applied through the button itself or by clicking on the background. The camera is already set to this view by default. The Left/Right and Front/Back Camera View buttons will display the avatar(s) facing the corresponding direction. The Camera Follow On/Off button can be clicked to hold the camera stationary or fix it to follow the main avatar. This functionality of this button is disabled, however, when the camera is not in free camera mode. The MoCap Offsets button displays a separate window containing a list of all of the joints of the avatar and boxes containing their current offset value, which is displayed in Figure 13. The joints and values are all generated through an XML file. These values can be altered and applied to the specified joint of the main avatar via this window. The last button, Lower/Upper Zoom, offers the option of analyzing the avatar's gait when zoomed in on the lower body and the upper body. Clicking the button toggles between lower body zoom, upper body zoom, and the default full body view.

Figure 12: The Santos shown with a prosthetic leg that is inserted as a result of clicking the Show/Hide Prosthetic button.

After viewing the online quiz developed by OGAL, substantial changes were made to the layout and capabilities of the quiz window to match the format used. In the top left corner of the quiz window, there are buttons for navigating between previous or next questions and a replay button. The bottom right corner of the quiz window contains a Submit/Continue button, and the bottom left corner displays a quiz completion progress bar. Upon the expansion of the quiz window, the user may begin the quiz after reading through the instructions on the introductory page. The quiz is XML generated, and it is relatively simple for the developer to modify various properties of each question. A major feature that has been added includes an option to auto-play a selected MoCap file at the beginning of each question. The motion will be played once with a view of the frontal plane, followed immediately by the same motion viewed in the sagittal plane. Clicking the replay button at the end of auto-play will replay the auto-played motion, while clicking the regular play button on the main toolbar will play the last selected MoCap file. In the XML file for the quiz, the auto-played motion associated with each question may also be set to automatically zoom into the lower body or upper body, as shown in Figure 14. The question format can also be set to either multiple choice (with or without an additional question/options) or a checklist.

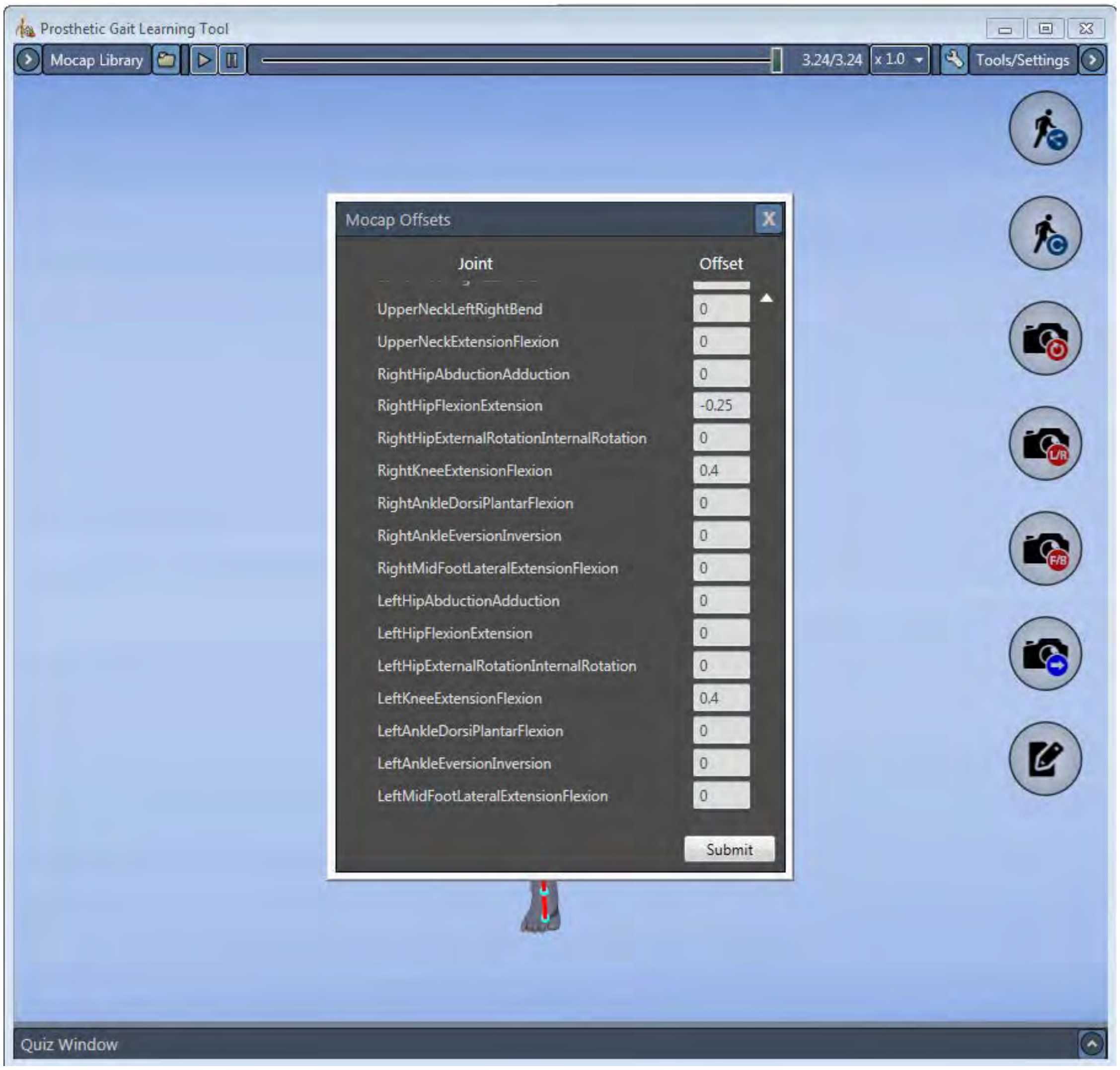


Figure 13: Any joint offset of the main avatar can be modified through the MoCap Offsets window.

The user is restricted from moving past the current question in the quiz until an answer has been submitted, but once an answer has been submitted, a feedback page is displayed. The user's response(s), as well as the correct answer(s), are displayed. If incorrect, the user's response is shown in red text next to a red X icon. If the user answers correctly, a green icon with a check mark is displayed. Pictures of the ideal gait during initial contact, mid stance, terminal stance, and mid swing are also provided on the feedback page; an example is shown in Figure 15. Furthermore, the main avatar is auto-played with the motion corresponding to that question, if one exists, with the control avatar playing next to it. The quiz developer can also specify if the feedback auto-play should be viewed using only the frontal or sagittal plane instead of the default showing the motion in both planes.

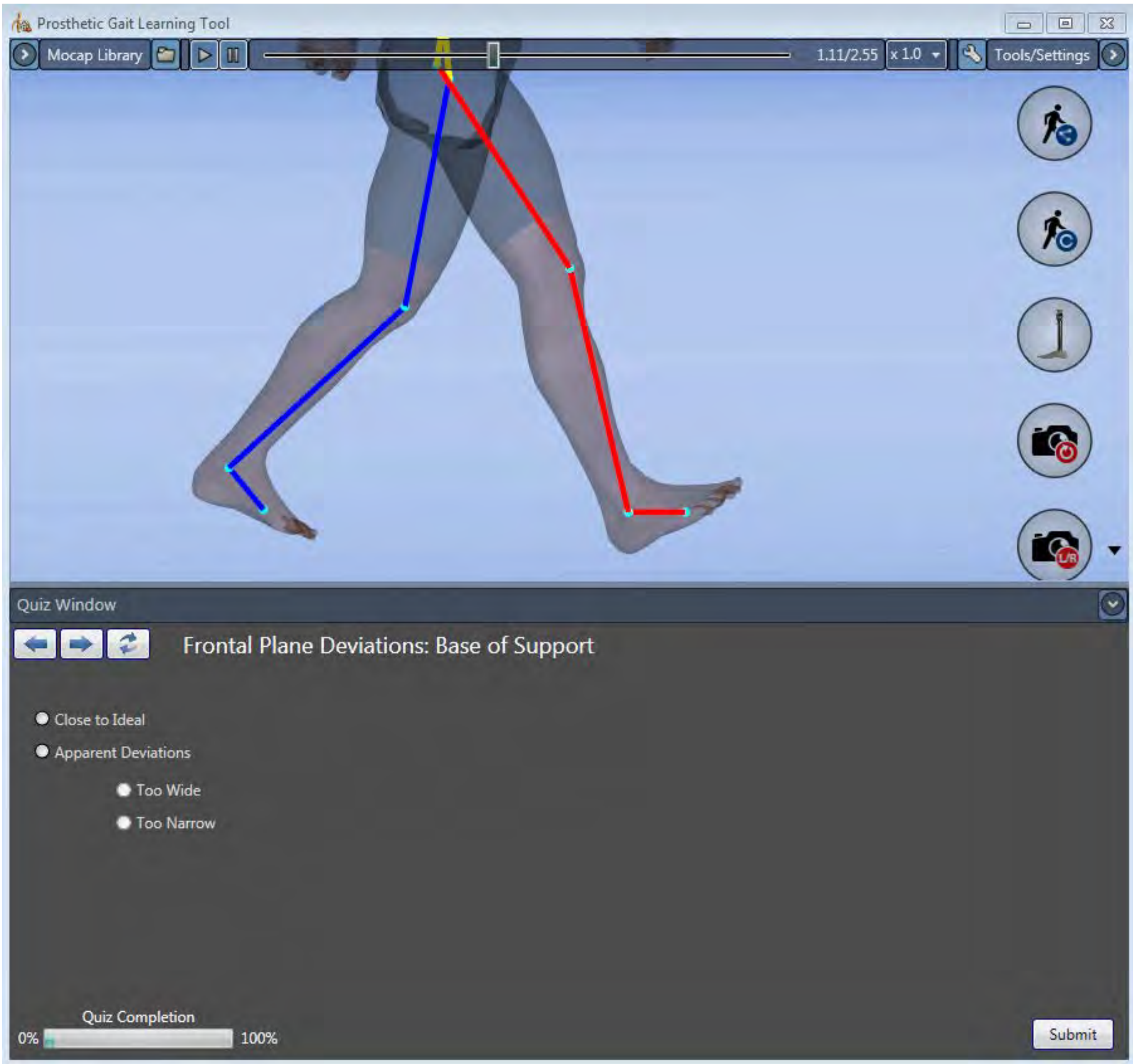


Figure 14: A multiple choice question in the current quiz specified to auto-play the MoCap file in lower body zoom.

An additional quiz option, which is currently being developed, will include joint manipulation. When this mode is enabled through the XML file, the user will be able to manipulate certain joints manually in the software.

Discussion and Conclusion

Most of the time and effort for MPL was focused on getting the IRB. The team had regular discussions during this year where the progress with various aspects of the project was evaluated and next steps planned. However, a lot of resistance to progress was felt due to the lack of IRB and actual data to visualize the tutorials. In the absence of such data, mock up data was created to make some progress on the gait deviations ratings development and the software development. Now that the team has IRB approval, it cannot wait to make further progress on all fronts with an approval of a No Cost Extension request. The development version of the software tool has been deployed at the OGAL lab to prove the capability of distribution of the software when it is ready.

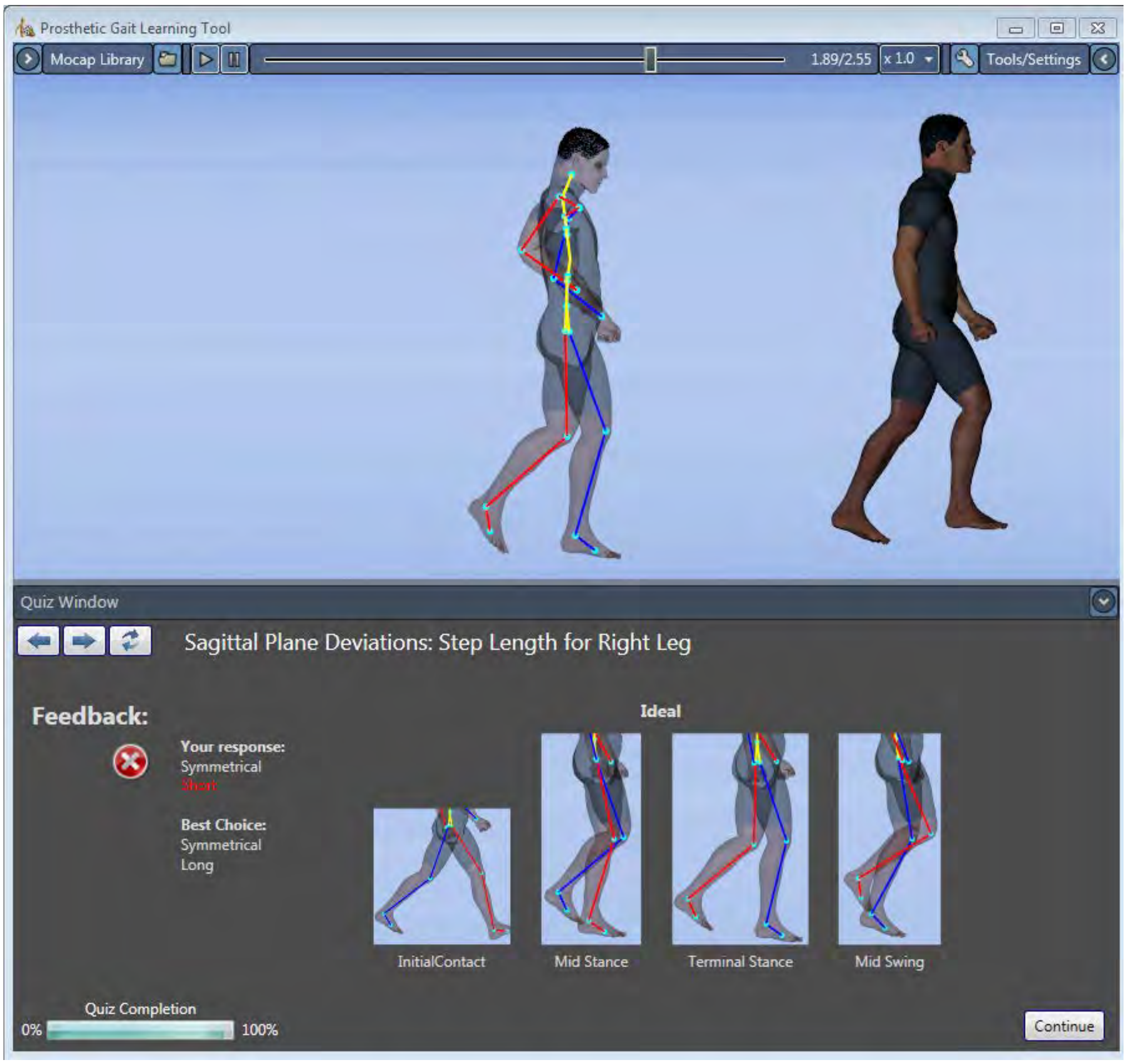


Figure 125: Quiz feedback page based on the user's response of one correct checkbox and one incorrect checkbox marked.

When the tool is fully developed, it will provide practitioners at all clinics and hospitals with access to advanced, computer-based gait analysis tools that are currently available at only a few state-of-the-art gait laboratories. The tool will aid in the training of service providers, ultimately improving the level of care they provide to wounded veterans. This system will, thus, provide a comprehensive training experience, allowing practitioners to benefit from a broad array of patient data previously collected by the US Army, thus bridging a critical gap in current medical training practices. The system will be developed to accommodate additional sequences captured over time, thus offering an extensible, distributable, and sustainable training library.

The results showed promising comparisons between the marker set given in Visual 3D and the recreation of the motion in the Santos environment. To date, motion capture data has successfully been transferred and recreated in the Santos environment.
Further work between labs should be concluded to streamline the process. Such items include:

1. Refine joint center calculations in Visual 3D
2. Refine in-house inverse kinematic code
3. Update Visual 3D model including
4. Unchecking “Calibration Only Landmark” tab for all landmarks
5. Removing unnecessary markers
6. Updating visual skeleton