# QualiWand: Towards Optimising Feedback for Motion Capture System Calibration

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**ABSTRACT**

This work in progress report presents preliminary results on the design of a feedback device that supports the task of calibrating a motion capture system. Calibrating motion capture systems is needed for their proper operation. It requires unique, dynamic actions and demands spatial awareness from the user. The goal of this inquiry is to find ways of providing feedback that will guide the user to perform the task with maximum efficiency so that the calibrated volume is optimal. This paper contains a description of the task and our initial design of a feedback system. We introduce QualiWand — and augmented calibration device that will enable us to study which feedback form is most optimal for the task. We then propose a plan for studying sound, visual and tactile feedback.

**Index Terms:** H.5.m [Information Interfaces and Presentation (e.g., HCI)]: Miscellaneous

## 1 INTRODUCTION AND RELATED WORK

Calibration methods for multi-view camera systems used for 3D computer vision often require the user to perform certain tasks in the physical world. Those tasks aim at setting up scenes with known geometry that can ideally be viewed in their entirety by all the cameras simultaneously with as little obstruction as possible. The images so taken are used to determine the parameters of a given projection model describing how a 3D point in the scene is mapped to 2D point on a camera's image plane [6].

The usual approach to "creating" scenes with known geometry is to introduce a physical reference object, sometimes called *calibration object*, into the measurement space. As Pribanić et al. [5] note, many different types of objects have been proposed over the course of years in an attempt to reduce manufacturing and other costs associated with the calibration object itself and lower the effort and expertise required from the user to perform a calibration. But even if the particular choice of calibration object enables users with little or no training to perform the steps outlined by the calibration procedure, is not always guaranteed that the user's actions will result in acquisition of image data that is suitable for the intended future measurement and 3D reconstruction. It is thus important that users understand which data is useful and which not with respect to the planned setup. Optimal solutions to that issue remain to be found.

Providing real-time feedback from the system during calibration task execution can guide the user by supplying information on past actions and directing the user to perform certain actions to obtain suitable calibration data for a given measurement. With this approach, non-expert users can perform a calibration with a reduced risk of having to repeat the procedure due to unsuitable data resulting from the user's actions.

In this work we examine the interactive aspects of a custom-designed calibration procedure based primarily on a one-dimensional calibration object, and used for a commercial multi-view motion capture system [3]. In particular, we study what type of feedback is appropriate for the custom-designed calibration procedure. Our aim is to investigate the feedback mechanism's effectiveness in reducing mistakes, improving the fraction of "good data" provided by the user and decreasing task execution time. Important aspects to consider in the feedback design are 3D perception augmentation and reduction of cognitive load. In a broader sense, we seek to investigate methods to design and evaluate feedback forms for complex dynamic tasks where the user constantly changes position and orientation.

Several past research efforts focused on augmenting the user experience of calibration tasks in different contexts. Flatla et al. [2] attempted making calibration tasks more pleasurable by introducing gamification. They designed games to determine color perceptibility, set optimal C:D ratios for input devices and measure the input range for a physiological sensor. Pfeuffer et al. [4] introduced a new gaze calibration procedure where they introduced the concept of blending the calibration into target applications. Our research can relate to these works as we are also aiming to make the calibration a more pleasurable experience. The work presented in this paper goes beyond the aforementioned inquires as it aims to provide a "sixth sense" not only augmenting the user experience of the calibration process, but also rendering the process more accurate.

## 2 CALIBRATION — AN INTERACTIVE TASK

We study the task of calibrating an optical, marker-based motion capture system designed by Qualisys AB[1]. A typical setup consists of four to up to a few dozens of cameras. Each camera can take up to 500 images per second of near-infra-red light reflected by retro-reflective near-circular markers. The calibration process of the Qualisys AB motion capture system makes use of a one-dimensional calibration object: two markers are mounted on a rigid bar [1], or wand, whereby the distance between the markers is known to a very high accuracy. Since images of two points alone are not sufficient for calibration [7], a second reference object is used. In particular, an L-shaped frame with four markers mounted to it is placed as a static reference object in the measurement space, whereby the distance between any two neighboring markers is again known with very high precision. The combination of measured markers from both the static and the moving object serves as the input to an algorithm that determines the best parameters, in terms of root-mean-square error, for the projection model by solving the so-called bundle adjustment problem [3].

The heuristic guideline for the user moving the wand through space is simple: the wand should be moved throughout the entire volume where 3D measurements will be made, and additionally the wand should be rotated uniformly in the entire volume. These simple instructions aim at reducing overfitting and bias towards a particular position and orientation of the line with respect to any of the cameras' optical axis. Figure 1 presents the calibration wand, the L-frame and a visualisation of the calibrated motion tracking volume.

While the calibration procedure and the heuristic guideline are easily explained to novices, the fact that there is currently no feed-

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[1] `http://www.qualisys.com`

(a) The wand (b) The L-frame (c) The calibrated volume

Figure 1: The calibration wand (a) features two reflexive markers placed on a T-shaped rod, while four static reference points are arranged on an L-shaped frame (b). As the distance between the markers is predefined, the system can be calibrated by analysing the view of the wand and the L-frame from multiple cameras. This results in a finite volume (c) where the system can reliably provide positional information.

back at all during actual task execution, leaves the user with no other choice then trial-and-error to gain sufficient experience to get “a feel” for what kind of wand movements lead to a satisfactory calibration. This situation can clearly be improved, as there are objective measures that can be used to give feedback in different possible ways on the quality of the calibration at any point during the calibration process itself. The quality can be measured using objective measures such as calibration residuals. Furthermore, the calibration can be assessed with respect to a volume defined by the user, that is, the volume within which the user intends to conduct motion measurements. Quality measures can be obtained on-the-fly thus creating a possibility to inform the user on the state of the calibration during the task.

## 3 Design

Designing for performing a complex and unique task is a challenge. Our initial design inquiry into the nature of the task and the context of the task resulted in identifying several feedback forms as possible solutions.

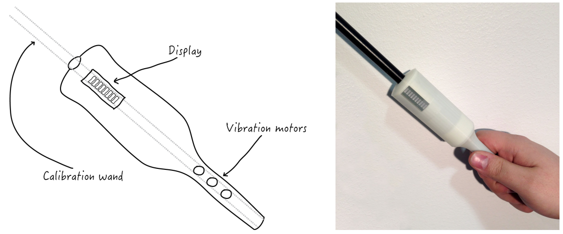
**Sound**. Auditory feedback may be useful as it does not require any additional infrastructure and it can easily accommodate multiple instructions. The drawback of sound is the inability to provide directional cues without extensive infrastructure such as directional speakers.

**Visual**. Feedback can be provided through a display informing the user on the quality of the calibration. Advantages of using visual feedback include the possibility of using multiple representations (e.g. colour, graphs, numbers) to convey information and the relative ease of implementation. On the other hand, it may be challenging to design a display that is easily visible throughout the entire task as the user changes their position rapidly.

**Tactile**. Using tactile feedback (e.g. vibration motors) is a promising opportunity. This feedback form can be easily embedded in the calibration wand and it can be provided with equal quality regardless of the position of the user. However, tactile feedback may be ambiguous and its precise design may require a significant effort.

We rejected several other feedback possibilities. Notably, we dismissed the possibility of using augmented reality. While visualising the space to be calibrated in augmented reality seems like a tempting idea, this solution is implementation-heavy and raises the fundamental problem of establishing the position of the augmented reality device when the system is not calibrated and cannot provide positional information.

For an initial inquiry, we constructed a prototype augmented calibration wand device.. The device is to be slid onto the calibration wand. The prototype features two types of visual displays (a bar graph and a numerical display) and a set of vibration motors built into the handle of the wand. The components are integrated into a 3D-printed enclosure. Figure 2 provides an overview of the components of the device as well as evidence of the implementation.




(a) A design sketch for QualiWand (b) Prototype implementation

Figure 2: QualiWand is additional device designed to be slid onto the calibration wand. In our augmented version, the user holds the wand through QualiWand (b). This enables several design possibilities such as providing two feedback types — visual and sounds (a).

## 4 Study design

We are planning to conduct a user experiment that will hope us determine optimal feedback forms. We will compare how users perform the calibration task with or without the help of extra feedback. We will compare four conditions: no feedback (baseline), audio, visual and tactile. Participants will perform system calibration within a predefined time in all four conditions (a within-group study) and Latin squares will be used to minimise the role of task order. Performance will be measured in terms of quantity (percentage of volume calibrated) and quality (calibration residuals). We will then run ANOVA to look for significant effects.

## 5 Conclusions

In this work in progress report, we presented our initial insights into the design of a feedback system supporting the motion tracking system calibration task. We provided a detailed description of the task and outlined different design possibilities for augmenting the task. This report also discusses our initial prototype and an experiment plan. We hope to continue the research effort, perfom our planned studies and reach conclusions on what the optimal feedback form is.

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