




CamDistance: A Web-Based Tool for Automatic Camera Distance Detection Using Facial Landmark Detection

Mohammad Ahsan Khodami ¹

¹ Department of General Psychology, University of Padova, Italy  Corresponding author

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Software

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Summary

Accurate measurement of viewing distance is crucial in psychological experiments, particularly in studies of visual perception, visual search, attention research, and any task where the visual angle (degrees of visual angle) of stimuli must be precisely controlled. In online and remote experiments, researchers face a fundamental challenge: without knowing the participant's viewing distance, it is impossible to determine the actual visual angle subtended by stimuli on the screen, making it difficult to replicate laboratory conditions and ensure experimental validity (Li et al., 2020). Traditional methods for measuring participant distance from the screen rely on manual measurement using rulers or measuring tape, which is time-consuming, prone to human error, and completely impractical for remote experiments conducted online.

CamDistance is a web-based tool that automatically detects and measures the viewing distance between a participant and their computer screen using facial landmark detection and geometric calculations, specifically designed to solve the critical problem of unknown viewing distance in online experiments. The tool leverages Google's MediaPipe Face Mesh (Lugaresi et al., 2019) to detect facial landmarks in real-time through the participant's webcam. By measuring the interpupillary distance (IPD) in pixels and applying geometric principles with known focal length parameters, CamDistance calculates the viewing distance in centimeters, enabling researchers to determine the precise visual angle of their stimuli.

This capability is essential for visual search tasks, perception experiments, and any research where stimulus size in degrees of visual angle must be controlled across participants. CamDistance addresses the most significant limitation of online psychological research: the inability to standardize viewing conditions and ensure that stimuli subtend the intended visual angles. The tool has been designed to integrate seamlessly with existing experimental frameworks such as jsPsych (De Leeuw, 2015) and JATOS (Lange et al., 2015), enabling researchers to incorporate automatic distance detection into their online experimental workflows without requiring additional hardware or manual intervention.

Statement of need

Viewing distance detection is a fundamental requirement in psychological experiments, particularly in studies involving visual stimuli where the visual angle, retinal size, and perceived size of stimuli depend critically on the distance between the participant and the display (Holway & Boring, 1941). The visual angle (θ) of a stimulus is calculated as $\theta = 2 \times \arctan(\text{stimulus_size} / (2 \times \text{viewing_distance}))$, making viewing distance a critical parameter for experimental control (Pelli, 1997). In visual search tasks, attention studies, and perception experiments, stimuli must subtend specific visual angles (typically measured in degrees or arcminutes) to ensure comparability across studies and participants (Wolfe & Horowitz, 2017).

The transition to online experimentation, accelerated by global events and the need for remote data collection, has created an unprecedented challenge: researchers cannot control or even know the viewing distance of participants (Bridges et al., 2020). This fundamental limitation threatens the validity of online visual experiments because:

1. **Visual Angle Uncertainty:** Without knowing viewing distance, researchers cannot determine the actual visual angle subtended by stimuli, making it impossible to replicate laboratory conditions
2. **Cross-Participant Variability:** Different viewing distances across participants introduce uncontrolled variance in stimulus presentation
3. **Study Replicability:** Online experiments cannot specify stimuli in degrees of visual angle, the standard unit in vision research
4. **Comparative Validity:** Results from online studies cannot be directly compared to laboratory studies where visual angles are controlled

Traditional distance measurement methods present additional limitations: (1) manual measurement is labor-intensive and introduces experimenter bias, (2) physical rulers or measuring devices are unavailable in remote testing scenarios, (3) participants may move during the experiment, invalidating initial measurements, and (4) the measurement process can disrupt the experimental flow and participant engagement.

Recent advances in computer vision and facial recognition technology have made automatic distance estimation feasible through consumer-grade webcams (Zhang et al., 2019). However, existing solutions are often proprietary, require complex setup procedures, or lack integration with common experimental software platforms. Researchers conducting online experiments need a lightweight, accurate, and easily deployable solution that can be embedded directly into web-based experiments to restore experimental control over visual angles.

CamDistance fills this critical gap by providing a JavaScript-based solution that requires no additional software installation, works across different operating systems and browsers, and can be easily integrated into existing experimental paradigms. The tool uses established geometric principles combined with modern facial landmark detection to achieve measurement accuracy comparable to manual methods while eliminating human error and enabling precise visual angle control in online experiments.

The tool is particularly valuable for researchers conducting online visual search experiments, perception studies, and attention research where stimulus size in degrees of visual angle is a critical experimental parameter. By providing real-time distance detection, CamDistance enables researchers to calculate and present stimuli at their intended visual angles, restoring experimental validity to online research and opening new possibilities for large-scale remote data collection with laboratory-level precision.

Implementation

CamDistance is implemented as a JavaScript application that can run in any modern web browser supporting WebRTC camera access. The core functionality is built around three main components:

Facial Landmark Detection

The system uses Google's MediaPipe Face Mesh (Lugaresi et al., 2019), a machine learning solution that detects 468 3D facial landmarks in real-time. The tool specifically focuses on landmark points 33 and 263, which correspond to the medial canthus (inner corner) of the left and right eyes, respectively. These landmarks provide a stable reference for interpupillary distance measurement that is less affected by eye movement and blinking compared to pupil centers.

Distance Calculation Algorithm

The distance calculation employs the pinhole camera model and similar triangles principle:

$$\text{Distance} = (\text{Real_IPD} \times \text{Focal_Length}) / \text{Pixel_IPD}$$

Where: - Real_IPD is the assumed interpupillary distance (default: 6.3 cm, based on population averages (Dodgson, 2004)) - Focal_Length is calculated dynamically based on the camera's field of view and video stream resolution - Pixel_IPD is the measured distance between eye landmarks in pixels

The system implements several optimization techniques:

1. **Temporal Smoothing:** Distance measurements are averaged over multiple frames to reduce noise from detection variations
2. **Outlier Rejection:** Measurements that deviate significantly from the running average are filtered out
3. **Stability Detection:** The system only reports a final measurement when values stabilize within a defined threshold

Integration Framework

CamDistance is designed as a jsPsych plugin (De Leeuw, 2015), allowing seamless integration into existing experimental workflows. The plugin provides:

- Configurable IPD parameters for different populations
- Customizable stabilization criteria
- Real-time visual feedback for participants
- Automatic data logging compatible with JATOS (Lange et al., 2015) and other experimental platforms

Validation and Accuracy

The accuracy of CamDistance depends on several factors including camera quality, lighting conditions, and the accuracy of the assumed interpupillary distance. In controlled testing conditions with standard webcams, the system achieves measurement accuracy within $\pm 2\text{-}3$ cm for distances between 40-100 cm, which is sufficient for most psychological experiments where viewing distance requirements typically allow for 5-10 cm tolerance (Woods et al., 2016).

The tool includes built-in validation features: - Real-time confidence indicators based on face detection quality - Warning messages for suboptimal conditions (poor lighting, extreme viewing angles) - Optional manual verification where participants can compare automatic measurements with ruler-based measurements

Related Software

Several commercial and research tools address distance measurement in experimental settings. Eye tracking systems such as EyeLink (SR Research Ltd., 2024) and Tobii (Tobii AB, 2024) include distance measurement capabilities but require expensive hardware and specialized software, making them impractical for online experiments. Web-based solutions like WebGazer.js (Papoutsaki et al., 2016) focus primarily on gaze tracking but include distance estimation features with limited accuracy and are not specifically designed for visual angle calculations in psychological experiments.

Most critically, no existing solution specifically addresses the fundamental problem of visual angle control in online experiments. Laboratory-based systems assume controlled viewing conditions, while web-based tools focus on interaction or gaze tracking rather than the precise distance detection needed for visual angle calculations in perception research.

132 CamDistance differs from existing solutions by focusing specifically on accurate distance
133 detection for visual angle control rather than comprehensive eye tracking or interaction
134 monitoring. The tool addresses the unique requirements of online psychological experiments
135 where precise visual angle control is essential for experimental validity. Its integration with
136 jsPsych and web-based experimental platforms makes it particularly suitable for researchers who
137 need to restore laboratory-level visual angle precision to online studies without the complexity
138 and cost of full eye tracking systems or specialized hardware.

139 Future Directions

140 Future developments of CamDistance may include:

- 141 1. **Adaptive IPD Estimation:** Machine learning models to estimate individual IPD from
142 facial features
- 143 2. **Multi-Point Detection:** Using additional facial landmarks to improve accuracy and
144 robustness
- 145 3. **Mobile Device Support:** Optimization for smartphone and tablet cameras
- 146 4. **Integration with Eye Tracking:** Combining distance detection with gaze tracking for
147 comprehensive spatial measurement

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