# Viewing Browser Content from Extreme Angles with Partial Perspective Corrections

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Displays viewed from extreme angles become perceptually distorted due to perspective projections. Perspective correction has been discussed as a remedy, yet there are few general and practical implementations available to users. This work explores modern browser technology for realizing perspective correction in practice, and whether partial perspective corrections is feasible. Three prototypes are explored, two where the corrections are configured manually and one where the corrections are determined automatically through camera-based vantage point measurements. Browser transformations are used to perform perspective corrections to content in real-time.

**CCS CONCEPTS** • Human-centered computing ~Visualization ~Visualization systems and tools

**Additional Keywords and Phrases:** Perspective correction, Transformation, Shared displays, Partial perspective corrections, Visualization

**ACM Reference Format:**

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## 1 Introduction

Displays are usually viewed from the front. However, if viewed from the side the display content is noticeably distorted due to perspective projections. Example use cases include participations viewing a projected presentation in a small meeting room, or a user watching a television in the living room from the kitchen. Humans are tolerant to perspective distortions as these match our expectations of the world. Although our visual system is capable of perceiving content that has been distorted due to perspective projections it may be uncomfortable or even lead to errors.

Perspective correction is a technique that has been extensively discussed in the literature. Although several academic texts discuss aspects related to perspective correction in general and several systems that employ perspective correction for specific use cases, there are few examples of general and practical perspective correction solutions readily available to users for general use cases. This work therefore explores pragmatic issues related to the use of modern web browser technology for realizing perspective correction in general.

## 2 Related Work

The relationship between the field of view and the distance between the viewer and the display was explored by Prouzeau et al. [11]. Bau et al. addressed the misreading of important information due to perspective distortions and explored perspective correction as a remedy [1]. Others who have explored perspective projection to information displays include [4, 7]. E-conic [7] is one example of a full system that tracks the user's position and adapts the visualization from the observer's vantage point by perspective corrections. E-conic requires a dedicated hardware configuration. Based on user evaluations of the system the authors concluded that the perspective corrections are beneficial in terms of performance for low level tasks. Similar results were observed for a system where a workspace was established with portable projectors [2]. This system assumed that the worker was stationary and there was no need to track the position of the user. Perspective adaptations have also been used in immersive CAVE displays [5], and for external view with cube displays [15]. The goal of perspective corrections is the opposite of typical 3D-visualizations where the goal is to achieve perspective [12, 13, 14].

In addition, perspective corrections have been applied to specific applications such as camera-based bar-code/QR-code reading [10] and vehicle control [9], in particular parking assistance [6], lane control [8], and in-vehicle heads-up displays [3].

## 3 Partial Perspective Corrections

Three prototypes were developed to assess the feasibility of realizing perspective correction with browser technology. All prototypes display the perspective corrected content embedded in an html iframe. The corrections are achieved by styling the iframe element with CSS transformations.

The two manual prototypes exposed the transformation parameters to the user allowing the user to fine tune the view with a set of sliders. One prototype exported a scaling and a shearing parameter (see Figure 1), while the other exported 3D transformations (perspective and X, Y and Z rotations, see Figure 2). The calibration image is shown in Figure 3.

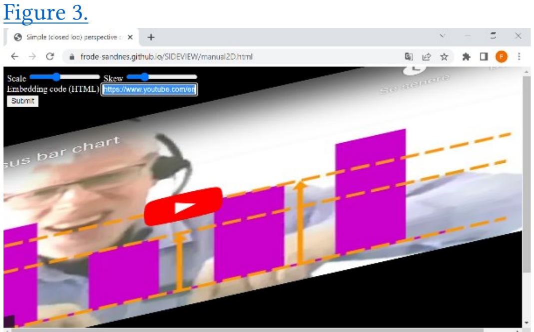


**Figure 1: Manual calibration of partial perspective correction of a YouTube video with scale and shear.**

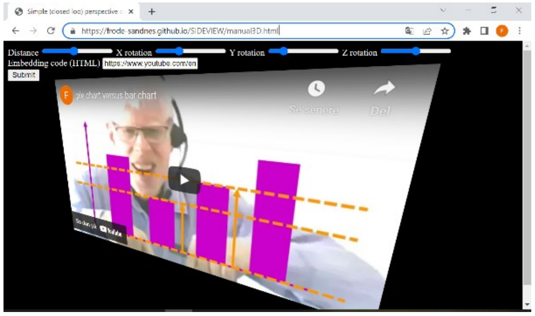


**Figure 2: Manual calibration of approximate perspective correction of a YouTube video with 3D transformations.**

**Figure 3: Partial perspective corrected calibration square from the viewers vantage point.**

The automatic prototype has two main parts, namely a view vantage point analyzer, and information view transformer. The vantage view analyzer was implemented by displaying a calibration image that is captured by a camera at the viewer's position. This calibration picture comprises four circles in red, green, blue, and magenta positioned at the corners of a square on the information display. The projected centroids of these circles are determined using basic image analysis techniques. Next, the mapping between the points of the square on the information display to the point of the quadrilateral on the camera plane is used to find the transformation between the two planes. The inverse of this transformation is used to find the corresponding quadrilateral points of the corners of a corresponding square on the camera plane on the information display.

The pack-projected quadrilateral on the visualization plane is used to determine approximate 2D transformations (scaling and skewing) that can be used to adapt the visualization to fit the viewer at the vantage point. When side viewing one dimension is shrunk and thus need to be expanded. The scaling factor is found by using the ratio of the longest vertical side to the longest horizontal side. The angles of the longest horizontal and vertical sides are used to define skew along the horizontal and vertical axis.

# 4 Discussion

The automatic perspective correction prototype was implemented without the need for a server infrastructure to mediate the communication between the smartphone used for calibration and the computer driving the display. This simplification comes at the cost of some inconvenience as the user needs to control two devices and copy the final transformation link from the smartphone to the display computer. Another use case is the smartphone for calibration and display, where the calibration image and visualization are casted to the information display. Manual calibration using scale and shear appears to be the optimal compromise between convenience and result. However, user studies are needed to confirm this. Such user feedback is also needed to assess whether the partial projection corrections suffice in practice. If performing just scaling corrections the result may be used by two viewers at either side simultaneously; a scenario that is not possible with true perspective corrections.

Another practical issue is that the content viewed needs to be embeddable, such as YouTube video links, as it is not possible to embed arbitrary content in an iframe to protect the users from cross site attacks. Although impractical, local style overrides may be one way for a user to configure a local perspective correction.

# 5 Conclusion

Although perspective correction for general displays is an attractive proposition it is also impractical because accurate information about the whereabouts of the viewer is needed. This is especially challenging if the person moves around, or if a display is shared. This ongoing work explores if (a) it is feasible for the user to self-adjust the correction parameters, and (b) to perform partial corrections that only adjust for the most noticeable distortions, notably scaling and shearing. The prototypes mentioned are available at https://github.com/frode-sandnes/SIDEVIEW/ and can be run at https://frode-sandnes.github.io/SIDEVIEW/.

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