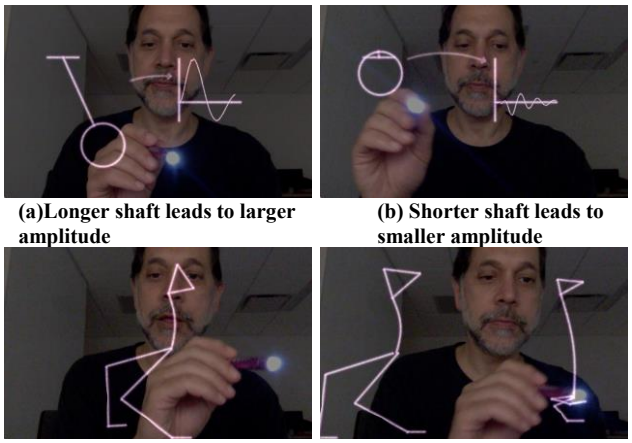
physics of the swinging pendulum properly reflects the shape that was drawn, see Figure 3a and Figure 3b.

(a) pendulums (b) shoes (c) dinosaurs

Figure 2: Geometric variation in drawing multiple glyphs
(a) The left glyph shows a pendulum with longer shaft and smaller bob, meanwhile the right glyph indicates a pendulum with shorter shaft and larger bob, which will affect their physical behavior.
(b) The upper glyph shows a shorted fish with larger head and the lower one shows a fish with longer body and smaller head. The length of the body will lead to different swimming speeds.
(c) The dinosaur in the left has longer legs than the right one. Therefore the left one will walk faster than the right now.

Similarly if a participant draws a walking creature, than the proportions of the different parts of the creature, such as its torso length the size of its legs, are recognized by Chalktalk and are used to modify the way the creature walks and otherwise behaves, see Figure 3c and Figure 3d.



(a)Longer shaft leads to larger amplitude **(b) Shorter shaft leads to smaller amplitude**

(c) Longer legs lead to larger movement **(d) Shorter legs lead to slower pace**

Figure 3: How physics of the swinging pendulum properly reflects the shape that was drawn

A fundamental decision was made that all drawing by participants be performed in a virtual plane that floats at a fixed distance in front of that participant, so as to best build upon our human ability to draw accurately in two dimensions. In contrast, the resulting recognized simulated objects exist in three dimensions, see Figure 4.

For example, a participant can make a drawing of what looks like an image of a hypercube. Then once that drawing has recognized by Chalktalk, the resulting interactive simulation object behaves just like a mathematical projection onto a three dimensional space of a four dimensional hypercube, see Figure 5.

(a) The polygon in coordinate system is three dimensional **(b)The whole AR scene is three dimensional**

Figure 4: See the objects in three dimensions

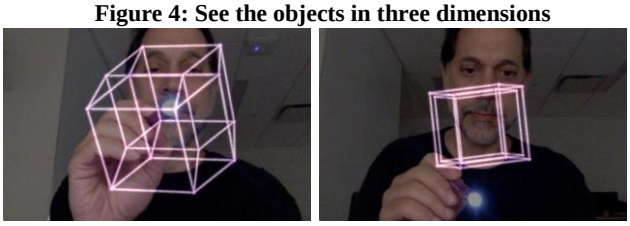


Figure 5: Looking into a hypercube in three dimensions

3 CONCLUSION AND FUTURE WORK

We have introduced Chalktalk VR/AR, a dynamic sketch-based simulation tool for face to face brainstorming in VR and AR. This approach preserves the immediacy of face to face collaboration. It also allows sophisticated simulation elements to be invoked and included in an emerging larger simulation. This approach of using freehand sketching to invoke simulation elements is well suited to the brains-torming process, as compared with less socially oriented approaches such as typing or choosing from menus. Also, the use of freehand sketching as an input modality allows participants to customize the properties of simulation elements during the course of their conversation, without needing to interrupt the flow of conversation to do so.

One potential drawback of Chalktalk VR/AR, as opposed to menu based approaches is that it requires participants to have a certain level of shared expert knowledge of the sketch language. However, we maintain that as VR and AR become more ubiquitous parts of our everyday communication, this general “language based” approach to visual support for face to face communication will become increasingly the norm, rather than the exception, in much the same way that natural language itself is a powerful and ubiquitous form of communication that relies on shared expert knowledge of the language being spoken.

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