Research Statement

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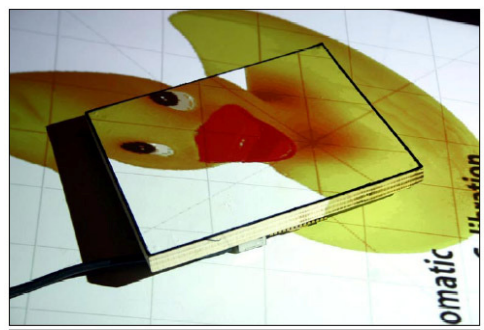
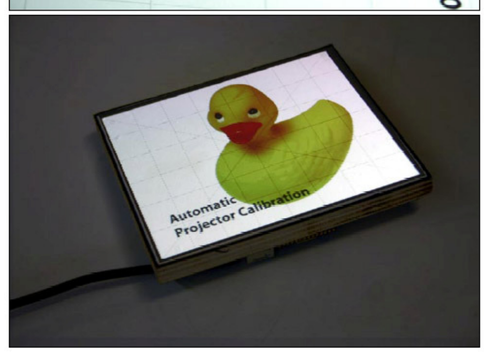
As researchers, one of our common goals is to expand our reach and our capabilities as human beings through the development of new technologies and new ideas. Often we use immense resources to explore this new territory. However, an unfortunate side effect of this essential activity is that the number of individuals that can participate in this search becomes smaller and smaller as the resources become greater and greater. My primary motivation in research is to develop and demonstrate new techniques that substantially increase the practicality and accessibility of technology putting it within reach of more researchers, developers, and end users. My work solves real world problems of applying research concepts by simplifying implementation and reducing system cost. This does two things: first, it enables more researchers to explore the domain advancing the state of research; second, it results in a more practical commercialization increasing distribution, adoption, and overall impact. While I have worked on a wide range of topics, I have been successful in this goal of increasing the practicality and reachability of advanced technology concepts throughout my research. To illustrate, I will describe three examples of my projects and how they have achieved this goal beginning with my dissertation work.

Projector-Based Location Discovery and Tracking

The computer graphics community has explored the power projected light has to create illusions that can reshape and transform our perception of our environment. We can create large multi-user multi-touch interactive surfaces, create highly immersive environments by stitching and coordinating multiple projectors, create view-angle dependent displays using layered projection, create variable resolution displays, alter the appearance of physical objects, and augment our environment with co-located information. Yet, few of these systems have had success in terms of commercial or consumer adoption. This is in part due to the expert knowledge needed to perform setup and calibration, as well as the need for typically expensive external tracking technologies to perform input.

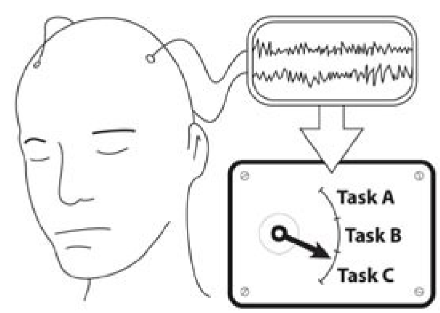




In an effort to overcome many of these limiting factors, I developed a novel method of location discovery and tracking using the projector itself. My approach is to place optical sensors in the projection area, project a sequence of binary Gray-coded patterns which uniquely identifies every pixel, and then decode the light patterns seen by each sensor to discover their locations in the projector's screen space. By using the projector to perform location discovery, many of the calibration and alignment issues of projector applications can be eliminated simplifying their implementation and execution. This technique is robust, accurate, fast, scalable, and very low-cost. Furthermore, it significantly outperforms computer-vision approaches along several dimensions of scalability and robustness. For example, location discovery time is independent of the number of tracked points and absolute point identity is inherent to the approach. The number of patterns required for location discovery has an O(log *n*) relationship to the number of pixels in the projection screen allowing it to scale easily to very high resolutions. Additionally, I developed a prototype capable of projecting the location discovery patterns using invisible infrared (IR) light at sufficient speed to perform interactive tracking while also capable of projecting visible light images. Imperceptible modulated IR light provides robust performance in variable ambient lighting conditions and does not disturb the visual experience of human observers looking at application content. My prototype design is highly compatible with the upcoming generation of LED illuminated DLP projector designs making it a commercially viable technique. Such a hybrid infrared/visible light projector would inherently enable an end user consumer to execute a large number of interactive applications currently explored only within the limited computer graphics research community such as: automatic projector calibration, automatic touch calibration, multi-projector stitching and layering, shader lamps, magic lenses, physical input worktables, tablet PC simulation, hand-held projection, multi-stylus input with ID, and more. This projector would also provide new input and output capabilities difficult or impossible using alternative approaches such as pointing on non-planar discontinuous surfaces of unknown geometry, variable resolution displays, foldable displays, and multi-sided display surfaces. Video demonstrations of this work can be found at: *http://www.cs.cmu.edu/~johnny/projects/thesis/* (mirror: http://jobapp.johnnylee.net/mirror/projects/thesis/)

By developing a technique for using a projector to perform both image projection and location tracking, I have greatly reduced the cost and complexity of implementing interactive projection and projector-based augmented reality applications increasing the accessibly of this technology. Recognizing this value, the technology has been licensed by a major interactive whiteboard manufacturer for touch calibration and licensing for use in immersive simulators, advertizing, and emerging projection technologies are currently in negotiation. There is a substantial amount of future work that can be explored using this capability as a development platform for location sensitive display surfaces as well as expanding this technique to other technologies such as laser scanning projection and use in mobile contexts.

Using a Low-Cost Electroencephalograph for Task Classification in HCI Research

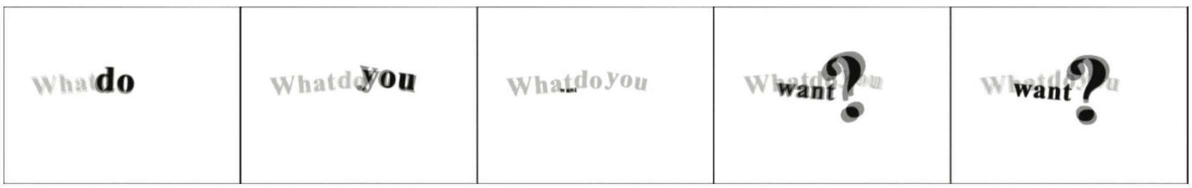


Brain-Computer Interaction (BCI) is an enticing idea rooted in the field of neuroscience and rehabilitation engineering. However, exploring how the benefits of this technology can be applied to able bodied individuals in the effort to give computers a better understanding of its user it is a relatively new idea. It may allow us to derive more direct measures of traditionally elusive phenomena such as task engagement, cognitive workload, surprise, satisfaction, or frustration. These measures could open new avenues for evaluation techniques or context sensitive system behavior. Because much of the work in BCI has grown out of the rehabilitation engineering and neuroscience domains, a large portion of previous research has relied on high-end devices costing between USD$20,000-$1,000,000. Despite its potential utility, the immense cost and medical expertise necessary to explore this technology places it out of reach for the majority of researchers.

In partnership with Desney Tan at Microsoft Research, I developed a successful experimental design and method of analysis that achieved task-classification accuracies comparable to extremely high-end electroencephalograph (EEG) systems using a USD$1,500 device. We were able to achieve a mean 3-way classification accuracy of 84% on mental tasks across 8 subjects. We also introduced the concept that if we do not attempt to claim a neurological basis for the source of our EEG signal, motion artifacts could be leveraged to improve task classification accuracy rather than removed as is done in traditional neuroscience research. This work also began to address how these technologies could be used in a realistic computing scenario with able-bodied individuals where movement is inherent to most tasks. When classifying a representative computing task with motion, our 3-way mean accuracy was 92.7%. These classification accuracies are extremely high in comparison to contemporary BCI work.

By providing experimental results demonstrating that accurate classifications can be obtained using a very low-cost EEG system and adapting the assumptions of the BCI community to HCI work, we have dramatically increased the accessibly of this technology lowering the bar for exploration within this domain. This research has helped establish the BCI work conducted at Microsoft Research today. The same approach can be applied to electromyography (EMG) signal detection providing an avenue for exploring direct muscular movement input devices.

Kinetic Typography



Kinetic typography refers to the art and technique of expression with animated text. Similar to the study of traditional typography of designing static typographic forms, kinetic typography focuses on understanding the effect time varying properties have on the expression and interpretation of text. Often used in film and television, kinetic typography has demonstrated the ability to add significant emotive content and appeal to expressive text capturing some of the qualities normally found in the spoken word. Authoring these animations typically involves a significant amount of technical and artistic expertise. Most animation tools used by kinetic typography designers do not scale well to handle very large numbers of objects or to generate many small variations quickly, both of which occur when animating text. The key frame approach to animation results in a significant amount of manual labor that is not easily reusable. Similarly, traditional animation programs do not easily handle dynamic content making it difficult to animate live streams of text.

As one of my first projects in my PhD program in 2002, I developed a Kinetic Typography engine that provided a programmatic extensible animation library designed specifically for authoring, manipulating, and representing animated text. The engine featured an innovative behavior system that allowed concatenation and compositing of simple animation behaviors into complex movements very quickly. It also allowed authored movement compositions to be re-used and applied to arbitrary amounts of text such as an entire book. We also developed Kinedit, a kinetic typography editor using the engine that featured a text editor metaphor for creating Kinetic Typography. Animation behaviors could be specified in the same manner that font properties could be specified. Video demonstrations of this work can be found at: *http://www.cs.cmu.edu/~johnny/kt/* (mirror: http://jobapp.johnnylee.net/mirror/kt/)

Six years later, the Kinetic Typography engine I developed is still actively used as a popular platform for class projects at Carnegie Mellon University. It has also become the basis for a number of papers by other researchers exploring the use of kinetic typography in mobile reading, where temporal presentation can be used to compensate for small screens, and instant messaging, where emotive expression is integral to the quality of communication. This animation platform has significantly increased the accessibly of this technology for students and researchers and provides a practical way of animating large amounts of text. I believe a general GUI animation authoring tool that exposes the versatility and re-usability of movement behavior the engine provides would be provide valuable alternative to the key frame animation driven programs of today.

Summary

While diverse in topics, all of my research projects have increased the accessibly and practicality their respective technologies expanding the number of people that can explore these domains. Part of my future work will include building upon these research platforms that I have already developed: projector-based location discovery and tracking, biometric input using low-cost EEG and EMG, and kinetic typography animation. Another component of my future work will be the continued exploration of techniques that can significantly increase the accessibility and practicality of interactive technology. For example, I have recently published a series of online tutorials on creating very low-cost multi-touch interactive whiteboards, head tracking, finger tracking, and video camera stabilizers using readily accessible technology. In total, these tutorials have received over **4 million** unique views (as of 1/1/08) and have generated a significant amount of both end user excitement and commercial interest (more information regarding this work can be found in my *Teaching Statement*). This increased level of awareness and accessibility raises level of technology adoption, exploration, and collaboration advancing both the state of research and human ability. This is my goal as a researcher.