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# Foundational Issues in Touch-Surface Stroke

## Gesture Design — An Integrative Review

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# 14 Summary and Conclusions

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We have reviewed and synthesized a body of research on stroke gesture interfaces. The synthesis is primarily focused on our own research but we also touched on the work of many other researchers. In this concluding section, we summarize key concepts and observations, main take-away conclusions, and forward-looking calls to actions.

First, stroke gestures fall into a multiple dimensional design space. The dimensions we identified include analogue versus abstract stroke gestures, stroke gestures representing symbols (particularly text) versus commands, order of complexity of stroke gestures, degree of visual-spatial

dependency, and implementation (finger versus stylus) and its associated sensor type. Each gesture system, such as the Apple iOS interface, the Graffiti text entry method for Palm devices, marking menus and the SHARK/ShapeWriter word-gesture keyboard, comprised a subspace in this multiple dimensional design space.

Although still limited, there is a body of scientific knowledge that is beginning to address the human factors and cognitive issues of stroke gestures, ranging from the motor control, to the visual, and to the memory aspects of human performance. Early basic human factors and usability studies on stroke gestures identified consistent patterns across users, in gestures they would anticipate for simple functions, such as move and delete. An important gesture performance topic is modeling a gesture's complexity so gestures or a set of gestures can be quantitatively optimized. The models that may apply here range from counting the number of line segments that can approximate a gesture to the CLC model that breaks down a gesture into curves, lines and corners, each modeled by a lower order model.

On the visual side, research has identified key computation features that can characterize the visual similarities of stroke gestures to users. Research has also shown that visual feedback has impact on some aspects of gestures such as size and closure (or, more generally, referential features), but not on global features such as the overall shape distance. Audio feedback has even less of an impact on the process of articulating gestures but it can help to inform the product of a gesture hence reducing the visual demand of a gesture interface. Both visual and audio feedback can potentially enhance the subjective and emotional aspects of gesture experience.

In comparison to point-and-click graphical interfaces (or tapping — zero order gestures on touch screens), gestures interfaces can be, optionally, made visual-spatially independent. Such independency means different functions can be activated with differently shaped gestures in the same place (or anywhere), resulting in three advantages — space saving, direct/random access to a large number of functions, and lowered visual attention demand—all may be desirable on a mobile device. The challenge, however, is how users can learn and memorize such gestures. We have shown that in one study users could learn 15 gestures on an unfamiliar word-gesture keyboard per 40 minutes of practice. We have also shown that 200% more gestures than keyboard shortcuts were memorized with the same amount of practice. Gestures, even if arbitrarily defined, afford the user the opportunity to elaborate and

more deeply encode their assigned meaning than keyboard shortcuts do. Furthermore, in contrast to the visual icons vs. keyboard shortcuts dichotomy, it is possible to design gesture interfaces that use the same motor control patterns between a visually guided process and a memory recall-driven process. Such motor control constancy facilitates skill progression. Marking menus and word-gesture keyboards are two examples of this.

There is a wide range of design principles for creating stroke gesture interfaces. These include making gestures analogous to physical effects or cultural conventions, gestures simple and distinctive, defining stroke gestures systematically, making them self-revealing, supporting chunking, and facilitating progress from visually guided performance to recall-driven performance. We also discussed how to support learning via game-based training programs and highlighted the usefulness of the expanding rehearsal interval algorithm for this purpose.

There are important implementation aspects of stroke gestures. We outlined the issues involved in separating commands from scope selection, and inking from stroke gesturing. We gave an overview of recognition algorithms and approaches for classifying stroke gestures, and toolkits that can aid implementers and designers.

As in any research field, research in gesture interfaces does not always impact mass products and the society. We raised three types of challenges that the research field faces in translating research results into products. First, the Qwertynomics effect helps conventional technologies that are “good enough” to prevail. The dominance of icon- and selection-based interfaces is likely to continue as a result. Second, user learning, even if paid off rather quickly in efficiency, remains a hurdle to gesture interface adoption. Third, gesture interfaces may need to be backward compatible with pointing or tapping types of interfaces. Finally, gesture interfaces need to be evaluated with various evaluation methods, such as conceptual analysis, mathematical analysis, controlled experiments, and studies of logs and actual deployments. It is important each design choice is evaluated in its application context.

Through this integrative we have demonstrated that stroke gestures have a deep and fundamental role in both user interface research and in consumer product development. Contribution from research to practice can span a wide range. At one end of the spectrum is addressing basic human performance questions, such as developing accurate models of the motor complexity of stroke gestures. At the other end, the

research field can contribute better engineering solutions, such as new recognizers, toolkits and systems.

We see many opportunities and challenges open for future research. By way of example, we name only the following four call-to-action topics. First, a strong model of stroke gesture complexity would contribute both theoretically and practically to the field. It could either be simpler than existing models or have a closed form, rather than being a combination of algorithms or equations for different types of strokes or stroke segments. Most likely it should reflect some form of entropy measure of the stroke gestures. Second, a model of the capacity, density and bandwidth of stroke gesture systems is currently lacking. Such a model could aid us in understanding the speed-accuracy tradeoff in stroke gesture interfaces, or, more broadly, the gain and cost in using machine intelligence in user interfaces. Third, we need deeper theoretical, empirical, and comparative studies in a variety of settings about the methods and approaches, to help users adopt and learn advanced gestures. These methods include crib sheets, marking menus, tracing-to-gesture progressions, as in ShapeWriter-like systems, and potential other designs. Fourth and more generally, we need to understand more deeply human memory and the skill acquisition mechanisms involved in gesture interaction.