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Foundational Issues in Touch-Surface Stroke Gesture Design — An Integrative Review

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Abstract

The potential for using stroke gestures to enter, retrieve and select commands and text has been recently unleashed by the popularity of touchscreen devices. This monograph provides a state-of-the-art integrative review of a body of human–computer interaction research on stroke gestures. It begins with an analysis of the design dimensions of stroke gestures as an interaction medium. The analysis classifies gestures into analogue versus abstract gestures, gestures for commands versus for symbols, gestures with different orders of complexity, visual-spatial dependent and independent gestures, and finger versus stylus drawn gestures. Gesture interfaces such as the iOS interface, the Graffiti text entry method for Palm devices, marking menus, and the

SHARK/ShapeWriter word-gesture keyboard, make different choices in this multi-dimensional design space.

The main body of this work consists of reviewing and synthesizing some of the foundational studies in the literature on stroke gesture interaction, particularly those done by the authors in the last decade. The human performance factors covered include motor control complexity, visual and auditory feedback, and human memory capabilities in dealing with gestures. Based on these foundational studies this review presents a set of design principles for creating stroke gesture interfaces. These include making gestures analogous to physical effects or cultural conventions, keeping gestures simple and distinct, defining stroke gestures systematically, making them self-revealing, supporting appropriate levels of chunking, and facilitating progress from visually guided performance to recall-driven performance. The overall theme is on making learning gestures easier while designing for long-term efficiency. Important system implementation issues of stroke gesture interfaces such as gesture recognition algorithms and gesture design toolkits are also covered in this review. The monograph ends with a few call-to-action research topics.

Contents

1

Introduction

The advent of a new generation of touchscreen smartphones and tablets is rapidly transforming the everyday computing experience of the masses. It is also shaping and changing research questions and priorities within the human–computer interaction research community. One research question is how to exploit the continuous stroke gesture capabilities that had not been previously available to most users on keyboard and mouse-based desktop and laptop computers.

In fact, stroke gesture research has a long history in the human–computer interaction (HCI) research field. Sketchpad, an early project commonly recognized as one of the beginnings of HCI research, was centered on graphical human–machine communication through stroke gestures [108]. About a decade later the influential textbook by Newman and Sproull [91] prominently featured stroke gestures as an input mechanism and described in detail how to implement a rudimentary stroke gestures recognizer. Buxton offered early insights into the cognitive functions, such as "chunking," that gestures may play in interaction [17]. Since the 1990s, stroke gestures as an interaction modality have been explored in a wide range of research prototypes for different application domains in the HCI research literature [25, 95, 128].

While stroke gestures have been continually explored in the HCI research literature, they only played a marginal role in HCI practice during the personal computing revolution in the 1980s and 1990s. The mouse and keyboard driven point-and-click style of Graphical User Interfaces (GUI) interfaces, also referred to as WIMP (Windows, Icons, Mouse, Pointer) interfaces, have been the dominant HCI paradigm in office and home computing for decades. The vision of using stroke gestures as an alternative way of interacting with computers, however, never ceased to exist in the research literature or in industrial and commercial efforts by companies and projects such as GO, the Apple Newton, the Palm Pilot, and the Windows Tablet. The spirit of a visionary entrepreneur in this space is well captured by Jerry Kaplan's tale of GO as a start-up venture [54]. Financially backed by Silicon Valley's best known venture capitalist John Doer and his firm (KPCB), GO offered a compelling vision of changing the fundamental user experience with pen-based computing, but nonetheless failed to gain market traction. In 1984, Casio released a wristwatch, the DB-1000, with a touchscreen that enabled the user to enter names and phone numbers by drawing them on the watch's screen. Later the Palm Pilot featuring Graffiti, a single stroke Roman letter-like gesture writing system, pioneered the mobile PDA (personal digital assistant) market and made the gesture user interface (UI) more mainstream. The success of the Blackberry smartphones turned the trend toward touchscreen and gesture UIs back to physical keyboards. Before Apple's iPhone, touchscreen and stroke gesture-based products remained on the fringe of personal computing. There could be many reasons for the difficult expansion of user computing from the keyboard and pointing device paradigm. One possible factor is that hardware limitations at the time prevented ultra-mobile devices from offering a truly good user experience. The other could be that the WIMP interfaces were good enough for most users' needs at the time. The tendency for a "good enough" but sub-optimal technology to persist in society has been theorized as path dependency by economists such as Paul David [31], but debated by others [79].

Today, stroke gestures are becoming increasingly more relevant to mainstream popular products such as the touchscreen-based smartphones and tablets. This is due to both technology-push, the development of new technology with little regard for current market demands, and market-pull, the market need guiding new technology development. Advances in hardware, including processing power, memory capacity, bandwidth, touch sensors, and battery technology have enabled handheld devices to provide a level of computing power only possible in desktop computers a few years ago. High-quality touchscreens have also begun to turn walls and tables into interactive computer media. In the marketplace, the value of directly manipulating objects with finger gestures on mobile devices and touch sensitive surfaces is suddenly being realized by consumers and manufacturers alike.

The stroke gestures used in today's popular touchscreen products tend to be relatively simple: sliding a document for panning; sliding a virtual latch to unlock; swiping across an item to delete. These simple gestures may be a solid foundation and the beginning of a new gesture interaction era. Technologies and paradigms that start with simple and incomplete functions often are more likely to succeed than those that start with complex but powerful functions. As users gain more experience with gesture-based interaction, they may be prepared for more complex and more powerful gesture functions in order to gain interaction efficiency. On the other hand, simplicity may well be the very reason for the success of the iPhone and other recent products. Researchers and designers have to consider the cost of learning and either minimize such cost or embed it in gradual use. Indeed, understanding and facilitating gesture learning is a theme of the current review.

Along with other colleagues in the HCI field, we have investigated various aspects of stroke gestures as an interaction medium. This monograph's primary goal is to provide a synthesis, summary, and interpretation of some of our research work on stroke gestures in the past decade, in a more accessible form and from a broader perspective than the original papers. Secondarily, we also selectively review some of the most fundamental behavioral research on stroke gestures by other researchers in the field. This monograph is not meant to be a complete review of stroke gesture research. The vast body of literature existing today on stroke gestures means that a complete review can easily turn into a catalogue or annotations of papers with no coherence or synthesis. We have limited the scope of this monograph to stroke gestures as commands and symbols. For gestures in sketching applications, Johnson and colleague's "Computational Support for Sketching in Design: A Review" in *Foundation and Trends in Human–Computer Interaction* [51] provides an overview of the area. For early work on gesture research and commercial efforts, the reader is referred to the book chapter on "Marking Interfaces" by Buxton [16]. The reader is also referred to Norman and Nielsen's critique of the "crisis" of gestural interfaces [92], in which they address the many challenges in the current generation of gesture interfaces, particularly the lack of consistency and discoverability.

The overall goal of the monograph is to provide a scientific foundation for future research and design of stroke gesture interfaces. We have aimed for a high enough level of abstraction so that researchers and designers who are not necessarily specialized in gesture research can understand the contents easily, while maintaining enough details so that the main logic behind the development of the research issues is supported.

The rest of this monograph starts with basic concepts, terminologies, and classifications of stroke gestures. We then briefly review a few sample stroke gesture user interfaces and systems, to ground the subsequent reviews of the more general and more abstract issues in stroke gesture research and design. After a brief survey of some of the early basic usability research on stroke gestures as an interaction medium, we focus the main body of the review on some of the foundational human-performance issues concerning stroke gestures in HCI including:

1. Measuring and modeling the motor control complexity of one or a set of stroke gestures;
2. Visual similarities of gestures;
3. The effects of visual and auditory feedback on gesture strokes;
4. The cognitive and memory characteristics of using stroke gestures.

After that we switch the orientation of the review from conceptual and empirical understandings of stroke gestures to the dimensions, rules, and guidelines in designing gesture systems. The focus of these sections is on how learning new stroke gestures can be facilitated in system design. We then deal with implementation issues in stroke gesture interfaces, including the separation of commands from scope selections, separation of stroke gestures from inking, the pros and cons of different gesture recognition algorithms, and toolkits that help programmers to design and implement stroke gestures in software applications. Finally, we summarize this monograph and raise a few key open questions, unanswered or under-explored in the research literature.

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