Argot: A Wearable One-Handed Keyboard Glove

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ISWC'14 Adjunct, September 13 - 17, 2014, Seattle, WA, USA
ACM 978-1-4503-3048-0/14/09.
http://dx.doi.org/10.1145/2641248.2641266

Abstract
The Argot glove is a one-handed, wearable input device that allows a user to type all English letters, numbers, and symbols without use of a traditional keyboard. The device design considers variables and constraints such as dexterity, feedback, mobility, learnability, speed of input, errors and false inputs, permanence, and comfort, as well as previous user knowledge. The glove design was informed by experimental investigations aimed at balancing tradeoffs between physical variables (reach, dexterity, haptics) and cognitive variables (learnability, text-entry method). It uses weak magnetic interactions during "key" presses to provide passive haptic feedback and reduce the need for precision in proprioceptive hand positioning.

Author Keywords
Wearable technology; Haptic feedback; Multitap; Arduino; Input language.

Introduction
Argot addresses the pervasive challenge of enabling text input in wearable applications without fully occupying the hands. Existing approaches to wearable text input like the Twiddler chording keyboard [1] often require that a device be held and/or strapped to the hand. While this naturally prevents the hand from being used for other purposes while typing, a hand-held

device can also cause add-on usability effects as the device must be retrieved prior to use, stowed following use, or held when not in use. Approaches that don't rely on button-presses, such as gestural input devices, often require that the user learn a new vocabulary or input language.

Background

Glove-based input removes the need for the user to hold or carry a device, by mounting the technology directly on the hands. While glove-based input devices are relatively rare, one significant precedent exists. The KITTY keyboard is a two handed, hand-mounted device which uses electrical connections between the tips of fingers and the thumbs to input information. Its layout is based on the standard QWERTY keyboard. The same fingers required to press a button on the keyboard correspond with that finger on the KITTY glove, which will make a connection with one of the contacts on the thumb. The contacts on the thumb correspond to rows on the QWERTY keyboard. Because the device is based on the user's existing knowledge, the interaction can be learned quickly and easily. Other connections on the fingernails and sides of the fingers allow for more complex data entry including numbers and special characters [2].

Argot (Figure 1) employs features similar to the KITTY design, most significantly the concept of electrical contacts between fingers being used in place of button-presses. However, as it is based on a QWERTY keyboard, KITTY requires two-handed input. The Argot glove alleviates this need while still leveraging prior knowledge by implementing a multi-tap or predictive-text input method. Finally, the Argot glove also addresses the challenges of proprioception in one-handed input (the challenge of finding the right place on a finger without looking) and of haptic feedback (knowing that a key has been successfully pressed) through a novel magnetic connection approach. Argot utilizes a simpler input language, and uses conductive thread and textile conductive patches to improve user comfort.

Figure 1. The Argot glove, showing magnetic conductive contacts.

Design Development

Determining design objectives, variables, and their relationships became the framework for developing the glove, conducting research, and producing the final prototype. Design objectives (dexterity, feedback, mobility, learnability, speed of input, and permanence) were identified through analysis of potential tasks completed by the user, environmental restrictions, human factors, and user needs. We also identified that previous user knowledge was a constraint that would help determine device viability.

Input language investigation was crucial in Argot's development. Defining device design limitations provided direction for the Argot glove development, as the input language defines the technical requirements of the glove (e.g. sensors vs. buttons, location and method of input, etc.). Learnability was the most important objective when choosing an input language. American Sign Language, Morse Code, and the Lorm alphabet were all investigated, but these were eliminated due to their general unfamiliarity and steep learning curve. The more familiar and widely used QWERTY and Dvorak keyboards were evaluated, but also found to not be viable options due to the required surface area and number of keys. Chording, although extremely efficient, was eliminated as a handheld device is required and does not solely rely on previous user knowledge. The final languages that were examined were T9/Predictive text and multitap. Both are based on the same 9-key systems and can be interchanged, and can be used without requiring the user to learn a new language. Multitap is a language that allows one contact to have several different inputs based on the number of times it is pressed, while predictive text suggests the most likely combination for the input sequence. They are both common languages used on mobile devices. Since multitap and T9 require fewer keys they are compatible with a single-handed device, which frees the user's second hand to accomplish tasks simultaneously while using the input glove.

User Testing

Argot is a user-centric device, and the design process relied heavily on user testing and prototype evaluation based on the previously-identified variables and objectives.

User testing began with a contact placement test to determine the optimum placement of input loci. Based off the decision to use either a multitap or predictive text input language, 15 buttons were needed in order to include space, shift, delete, and number lock buttons, as well as the ground contact used to make connections. The 15 locations illustrated in Figure 2 were chosen by evaluating the qualitative results of an ink test where subjects were asked to touch all locations within reach of the thumb on the surfaces of the other fingers, using an inked thumb. This allowed for measurement of the usable surface area on the hand and fingers. In conjunction with subjective participant responses, we identified the sub-set of most comfortable, easily accessed locations (Figure 2).

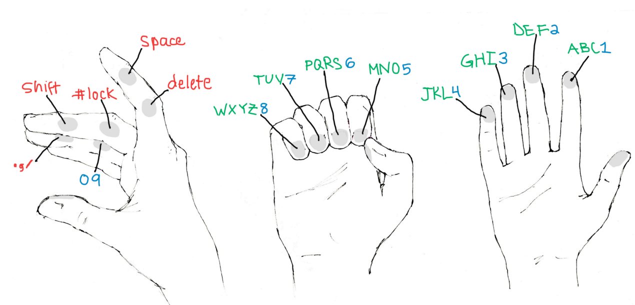

Figure 2. The Argot glove keymap.

30 connections were tested and the final locations on the finger pads, fingernails, and side of the index, middle, and third finger were chosen based on the degree of difficulty of each test, and user preferences.

Feedback, whether auditory, visual, or tactile, is crucial to the success of an input device. A computer keyboard, for example, provides auditory and tactile cues that each button-press has been successful. Tactile cues help the user to find keys without looking for them. Many textile-based solutions do not not afford this same kind of feedback, and can therefore be fatiguing, resource-intensive, and error-prone. For example, without feedback to confirm a successful button-press (e.g. a "click"), users often press too hard on soft switches, which is fatiguing and can cause pain. Feedback preference was tested using rubber and metal membrane switches, vibrating motors, and small magnets. Users preferred strong, instantaneous feedback that was small, localized, and non-strenuous. This led to the selection of magnets as a feedback mechanism, because they provide both tactile and auditory feedback without compromising the design (low bulk, low visibility) and user's comfort (minimal pressure points, minimal bulk).

The final developmental user study combined the chosen input language (multitap) and input locations into a testable prototype to determine if a learning curve existed and if text input was too mentally or physically strenuous. Participants were shown a keymap and asked to type "The quick brown fox jumped over the lazy dog" on their own fingers. Time to completion and errors were measured.

The results of the test showed that a learning curve did exist and that after each trial the user speed of input increased while errors decreased. The test reinforced the importance of adding feedback to our final prototype, as it would improve accuracy and user satisfaction.

Figure 3. Glove assembly and trace routing, showing insulating film.

Device Construction and Hardware

The Argot glove (Figure 3) is made of multiple polyester/spandex blend stretch knits and conductive textile patches. The different textiles allow for maximum mobility, comfort, and breathability. The spandex blend fabrics move and stretch with the user and do not inhibit activity or the sensory functions of the hand and fingers. The design features fourchettes between the fingers and a separate thumb piece to improve range of motion. To protect the integrity of the electronics, all conductive stitching is insulated using fusible stitchless bonding film (Figure 3).

15 conductive patches create the input loci and include a layering system to enclose magnets within the conductive assembly. The conductive patch layup is shown in Figure 4.

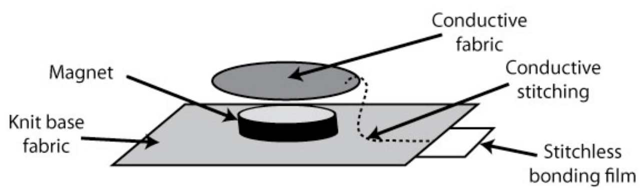

Figure 4. Conductive patch assembly that creates magnetic contacts for key presses.

Argot currently functions using the multitap input language, but is capable of both multitap and predictive text input. As an input method, the glove concept can interface with a wide variety of systems. However, as a proof-of-concept, we demonstrate Argot connected to an Arduino microprocessor and LCD screen. (NB: The current implementation partially impedes wearability and comfort due to the large LCD screen. In practice, the glove would not inherently require an on-body graphic display

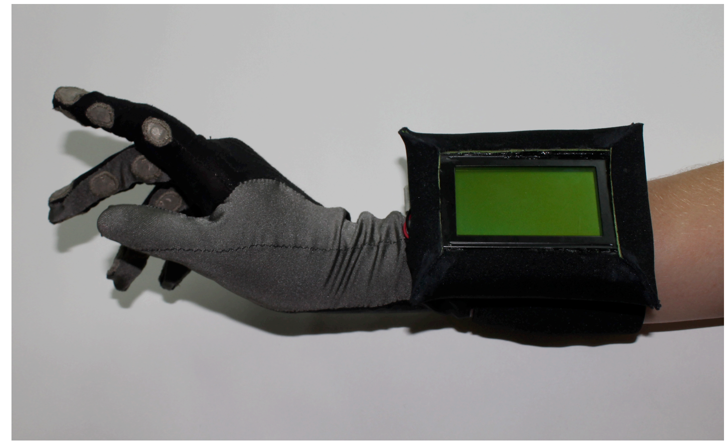

Figure 5. Argot glove with LCD screen.

Conclusion
Argot presents a novel approach to one-handed text entry that does not rely on a hand-held device. Further, it improves usability through passive haptic feedback and ergonomic key placement. The current implementation provides a proof-of-concept demonstration of a wearable device that has the potential for implementation in many contexts and for many user groups.

Acknowledgements
This work was supported by the Minnesota Space Grant Consortium. We would like to thank David Fitts and Haifa Moses of NASA JSC for their assistance and guidance in the development of this work.

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