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# Métamorphe: Applications for Shape-Changing Keyboards

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**Abstract**

We present Métamorphe, a novel shape-changing keyboard with keys that can be individually raised and lowered. Métamorphe augments the output of traditional keyboards with haptic and visual feedback, and offers a novel design space for user input on raised keys using new gestures (e.g., squeezing or pushing the sides of keys). We detail the implementation of Métamorphe, describe its properties, and discuss possible applications including command selection.

**Author Keywords**

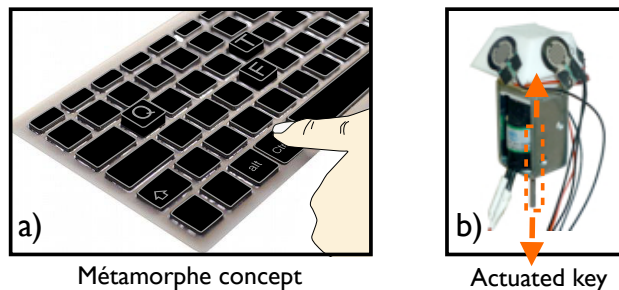
Height-changing keys; augmented keyboard

**ACM Classification Keywords**

H.5.2. Information interfaces and presentation (e.g., HCI): User Interfaces – Interaction Styles.

**Introduction**

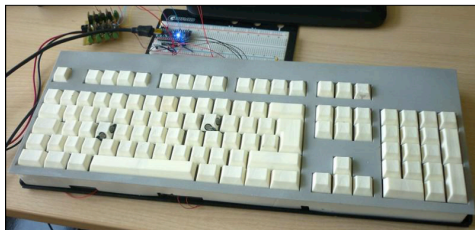
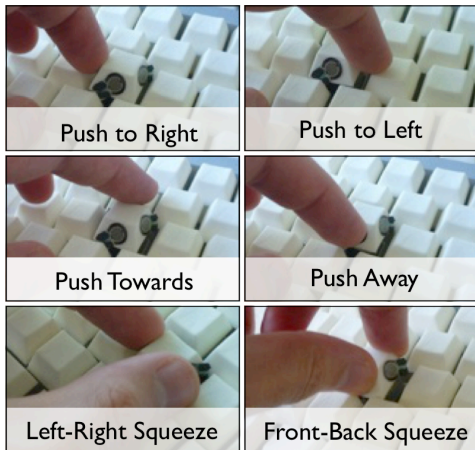
We investigate how shape-changing interfaces can modify the way users use traditional input devices such as keyboards and mice. We designed and built Métamorphe (Figure 1), a novel shape-changing keyboard. While Métamorphe retains the form factor, layout, and tactile qualities of a traditional keyboard, it embeds solenoids that can raise individual keys, and adds force sensors to the sides of the keys, allowing a variety of novel gestures to be performed.



**Figure 1.** a) The Métamorphe keyboard raises a subset of hotkeys when users press the CTRL key. b) Each key can be individually raised with an embedded solenoid, and contains force sensors that allow a variety of novel gestures to be performed on the key.

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**Figure 2.** Top: the physical manipulations that can be detected on each key. Bottom: our Métamorphe prototype.

The novel input and output capabilities of the Métamorphe keyboard raise interesting research questions: Is the increased interaction vocabulary useful and usable? How should designers use the new input primitives? Do raised keys improve performance for eyes-free key selection? In which scenarios do shape-changing keyboards have an additional value?

We first present the system. We then discuss five potential scenarios for the Métamorphe keyboard. In particular, we show how Métamorphe can favor the guessability, learnability, and eyes-free selection of hotkeys. Finally, we report results of two user studies before concluding.

### Related Work

Métamorphe is related to shape-changing input and output devices such as mice [3], keyboards [5], interactive surfaces [6], and displays [4]. However the Métamorphe's shape-changing keyboard differs from these earlier works, as its rising keys and force sensors provide a unique modality of shape changes.

Métamorphe is also related to augmented keyboards such as the Optimus [7], which contains a small screen on each key, or TypeRight [2], which provides haptic feedback to prevent errors during text entry. Métamorphe not only provides visual and haptic feedback, but also enables novel key gestures.

### The Métamorphe Prototype

The Métamorphe prototype [1] is shown in Figure 2-bottom. It is built atop a regular HP KU-0316 USB keyboard. It reuses both the mechanical and the electronic components of the original keyboard. However, it also embeds BLP Series 134 6V (30 $\Omega$ )

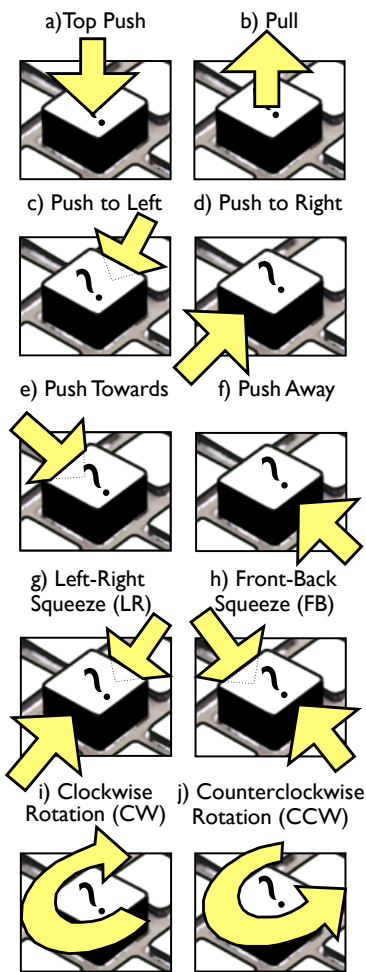
push-type solenoids in each key (Figure 1-b), so that they can be individually raised. Each Métamorphe key has four functional positions. One dimension is set by the computer: *raised* (the key is higher than the rest of the keys) or *unraised* (the key is in its regular position). The other dimension (*pushed* or *not pushed*) is controlled by the user's input. The magnitude of the height change for actuated keys posed a critical design factor for Métamorphe. Pilot studies showed that a key height of 4 mm is easy to perceive but does not impede ease of use. Finally, dynamic Métamorphe keys allow users to perform a large inventory of key gestures, as shown in Figure 2-top. Gestures are detected by force sensors attached to the four side faces of the keys.

We equipped our prototype with eight functioning dynamic keys, two of which embed force sensors; this is sufficient to allow a thorough exploration of the Métamorphe design space.

### Output: Haptic and Visual Feedback

Métamorphe transforms the keyboard into a haptic display with its height-changing keys. When a key is raised, the height difference compared to other keys provides a tactile or kinesthetic cue that can be used by users to confirm that the desired key has been reached. A raised key can also be used as an eyes-free landmark to help locate a nearby unraised target key. Users reach the raised haptic landmark, and then perform a quick ballistic movement towards the target location.

In addition to its haptic feedback, a raised key also provides visual feedback, since it looks distinct from the surrounding keys. These visual cues can be useful, particularly for novice users.



**Figure 3.** Design space of raised key gestures.

### Input: Novel Gesture Vocabulary

Métamorphe’s raised keys introduce a novel design space for key input. On a standard keyboard, a key can be *pushed*, *held*, and *released*. However, Métamorphe’s raised keys allow users to interact with several faces of the raised keys, enabling the 9 new gestures shown in Figure 3. Six of these new gestures have been implemented in our current prototype (Figure 2).

Users can *directionally push* (or *side push*) any of the four sides of a key, as illustrated in Figure 3-c-f. Directional pushes require only one finger, and allow for varying placement of the finger on the side of the raised key. Users can also *squeeze* a key with two fingers along the X-axis (a *Left-Right Squeeze*, Figure 3-g) or the Y-axis (a *Front-Back Squeeze*, Figure 3-h). Raised keys can also be rotated *Clockwise* and *Counterclockwise* (Figure 3-i-j). Finally, users can *Pull* a raised key a small distance upwards (Figure 3-b). This novel vocabulary of gestures dramatically increases the expressiveness of the keyboard’s input.

### Applications

We envision several applications for Métamorphe involving hotkey usage, text entry, games, etc.

#### Hotkey Usage

Hotkeys are an efficient way to select commands with a keyboard. However, many users – even experienced ones – do not use them. Novice users may be not aware of hotkeys, and intermediate users may find them a challenge to learn due to non-intuitive mappings. Expert users may still have difficulties accurately reaching keys without looking at the keyboard. While Métamorphe can act as a traditional keyboard for text entry, it can also improve hotkey

usage. For instance, it can favor the *discoverability of hotkeys*; pressing the Control key could raise a subset of hotkeys, revealing the most frequent ones. Some keys could also be raised when the cursor hovers over an object to indicate commands applicable for this object. Métamorphe can also increase the *guessability of hotkeys*, since the novel gesture input vocabulary offers increased flexibility to map commands to hotkeys. For example, semantically-related commands such as “Save” and “Save As” could be assigned to different gestures on the same key ‘S’, and symmetrical commands like “Previous” and “Next” could be assigned to opposing push gestures on the same key. Finally, it can make *hotkey selection* easier, since expert users can first use their spatial memory to develop a rough idea of the physical location of the desired hotkey on the keyboard, and then use Métamorphe’s haptic feedback to accurately relocalize the hotkey without looking at the keyboard.

#### Text Input

Métamorphe could be adapted to predict the next character in a string of text and automatically raise that key to (subtly) prompt the user and avoid spelling errors. This capability would be most appropriate with short and constrained text entry. For instance, if users must enter the name of a city in a form, and begin entering “Pari”, the system could suggest ‘S’ (for “Paris”) by raising that key. In addition, rising keys could provide tactile hints when learning typing skills.

#### Gaming

Raised keys could indicate a ready to use action (e.g., a spell), and the increased vocabulary could provide additional game controls.

### *Security*

Métamorphe could provide additional security features for password entry, since passwords could consist of both characters and gestures. This would increase the keyspace of inputs to the system, and could make passwords easier to remember because users could incorporate spatial memory.

### *Tangible Interfaces*

Physical controls could be provided on-demand for a wide variety of tasks. For instance, an on-screen dialog with three slider widgets could raise three keys to provide tangible controls for each widget.

### **User Studies**

We conducted two user studies in the context of hotkey usage. The first was a user-defined interface study that provided information about the mental models that users associate with raised keys, and demonstrated that users readily incorporate the novel input capabilities of raised keys to highlight semantic relationships between commands. The second study evaluated the impact of raised keys on the eyes-free selection of hotkeys, and showed that 1) raised keys are easier to locate on a keyboard than unraised keys, and 2) raised keys act as haptic landmarks, making it easier to locate neighboring, unraised keys.

### **Conclusion and Future Work**

We have presented Métamorphe, a novel keyboard with height-changing keys that provides haptic and visual feedback. As an input device, Métamorphe also offers a novel vocabulary of gestures, which increases the number of available actions on each key. We presented several applications for Métamorphe, and demonstrate how Métamorphe can improve hotkey usage.

Solenoids are an appropriate technology for shape-changing keyboards. However, there are also several challenges that need to be investigated further. Because solenoids require continuous power to maintain a key in the raised position, they necessitate heat dissipation. In addition, because they must be able to lift the key cap, their own weight, and the sensors, they may require overvolting to generate sufficient mechanical power (19V for 50ms). From a scalability point of view, each key has 4 sensors and 1 actuator, resulting in a large number of connecting wires for the entire keyboard; additional work would be required to miniaturize the system. Finally, we aim to integrate screens into each key, combining the advantages of the Optimus and Métamorphe.

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