# Typing in Thin Air
# The Canesta Projection Keyboard – A New Method of Interaction with Electronic Devices

**Helena Roeber, John Bacus, Carlo Tomasi**[1]
Canesta, Inc.
2833 Junction Ave., Ste. 200
San Jose, CA 95134 USA
+1 408 435-1400
[hroeber,jbacus,ctomasi]@canesta.com

## ABSTRACT
Canesta Keyboard™ is a novel interface to electronic devices that consists of a projection system and a sensor module instead of the mechanical switches of a traditional keyboard. Users input text by pressing keys on a projected image of a keyboard. This paper describes the advantages and drawbacks of this interface compared to existing input methods for mobile devices in terms of data entry speed, error rate, user satisfaction and physical size as revealed through usability testing.

**Keywords:** Mobile devices, text input, keyboard, machine vision, projection keyboard, virtual keyboard, PDA

## INTRODUCTION
As processing power and functional capabilities of mobile devices have increased over the past few years the demand for fast and accurate text input mechanisms has steadily increased. So far, voice and hand writing recognition, thumb keyboards, and on-screen keyboards have not met users' expectations of high input speed and low error rates in a portable package[1].

The Canesta Keyboard leverages users' familiarity with the mechanical keyboard while providing a lightweight, portable, and low power input solution. Familiarity accelerates the user's acceptance of an input mechanism that provides only limited tactile feedback and 'feels' differently from a mechanical keyboard.

## THE CANESTA PROJECTION KEYBOARD
The Canesta Keyboard projects the image of a keyboard onto any flat surface and allows the user to input text by typing on the projected keys. Each keystroke is accompanied by an audible "click".

The components of Canesta's projection keyboard are a pattern projector, a light source, and a sensor module, that can be integrated in any electronic device.

The pattern projector displays the keyboard layout on any flat surface. The light source emits a plane of infrared light slightly above the typing surface. The sensor module detects the intersection of fingers with the infrared light. Software algorithms interpret the data generated by the sensor module into mouse and keyboard events for the electronic device.

**Figure 1. Canesta Keyboard**

The prototype device used for usability testing is shown in Figure 1. The layout used for testing is as an adaptation of the QWERTY- keyboard as shown in Figure 2. Each of the alphanumeric keys in the layout is 17 by 17 mm similar to that of many laptop keyboards. The top row of the keyboard layout consists mostly of application shortcuts that prove useful with Portable Digital Assis-tants (PDA's).

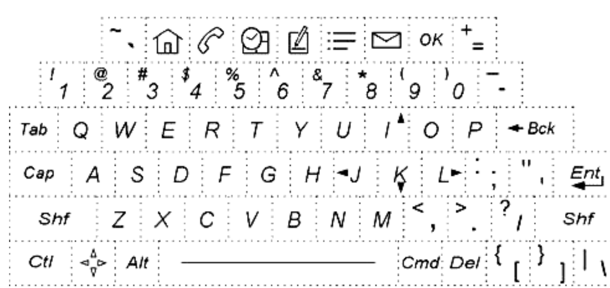


**Figure 2. Keyboard Layout**

[1] Carlo Tomasi is currently with Duke University


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## USABILITY TESTING

The goal of the user studies was to evaluate the Canesta Keyboard relative to other text input devices in terms of error rate, input speed and user satisfaction. Additional testing and surveys were conducted to identify usability concerns as well as to obtain subjective satisfaction and fatigue ratings after prolonged use.

A benchmarking study was used to compare performance of the Canesta Keyboard with mechanical keyboard, thumb keyboard and Graffiti performance. During this study, eleven subjects were instructed to repeatedly type the sentence 'The quick brown fox jumps over the lazy dog.' for 2 minutes without correcting their errors. The experiments were done using an early prototype of the Canesta Keyboard and commercial releases of the other devices. After using each device, the user was asked to evaluate the input device in terms of fatigue. The order of device testing was changed between users.

Additional studies to identify usability concerns and user satisfaction ratings were conducted continuously while the technology evolved. 65 test subjects participated in short phrase and paragraph transcriptions of approximately 500 keystrokes per session combined with post-test interviews.

The subjects of all studies included novice and experienced users of the Canesta Keyboard. All users regularly type on mechanical keyboards as part of their work.

## USABILITY STUDY RESULTS

The benchmarking and other usability studies showed favorable results for the Canesta Keyboard in comparison to other input methods and successfully identified usability concerns unique to the Canesta Keyboard.

### Data Input

In the benchmarking study, the Canesta Keyboard users were able to input text approximately 1.7 times faster than on thumb keyboards and 3.3 times faster than using Graffiti. In turn, average text input on a mechanical keyboard was 1.39 times faster than on the Canesta Keyboard. On average, the adjusted typing rate for the Canesta Keyboard was 37.7 Words Per Minute (WPM) and the average error rate (number of errors/number of characters) was 3.7%. Expert users were able exceed 60.4 WPM unadjusted. Average fatigue ratings were lowest for Canesta Keyboard. The results are shown below.

| Input Device | WPM (StDev) | Error % (StDev) | Fatigue 5=highest (StDev) |
|---|---|---|---|
| Graffiti | 14.0 (6.1) | 13.6 (10.8) | 1.4 (1.3) |
| Thumb Keyboard | 27.6 (4.8) | 2.2 (1.8) | 1.6 (0.7) |
| Mech. Keyboard | 64.8 (17.3) | 1.8 (0.9) | 1.2 (0.8) |
| Canesta Keyboard | 46.6 (9.8) | 3.7 (2.4) | 0.7 (0.6) |

**Table 1. Canesta Benchmarking Results**

### User Satisfaction

User satisfaction ratings for the Canesta Keyboard were high for most of the users tested. However, some touch typists encountered text input difficulties and rated satisfaction lower. Additionally, a number of users commented that they would prefer a larger keyboard to the one used in this study.

As a result of our studies, a correlation between a user's typing style, performance, and user satisfaction with Canesta Keyboard could be established. While the average satisfaction level with Canesta Keyboard was 4 (on a scale of 1 through 5, where 5 is highest), lower satisfaction ratings and higher error rates were observed among touch typists who tried to rest their fingers and type without looking at the keyboard. Users who frequently look at the keyboard reported high first-time usage satisfaction ratings and low error rates.

An additional area of investigation was whether users are distracted or suffer decreased performance when their typing fingers block part of the projected keyboard pattern from reaching the typing surface. This concern proved unfounded with all of the test subjects, presumably because the obstructed areas of the keyboard are covered by the user's hands and are thus not visible anyway.

## CONCLUSIONS AND FURTHER WORK

Our studies have shown the Canesta Keyboard to be a viable input mechanism for text entry into mobile devices. The Canesta Keyboard outperforms thumb keyboards and Graffiti in terms of input speed, comfort and user satisfaction. While lack of traditional tactile feedback may pose an initial problem to some, most users were quick to achieve fast text input with low error rates. As tactile feedback can only be introduced at the expense of portability (e.g. an embossed typing surface), sound can be used to compensate for limited tactile feedback. While a larger key size might increase user comfort, the resulting larger work area will decrease portability. Further work will be conducted to determine the impact of a full size keyboard on speed, error rate and user satisfaction.

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## REFERENCES

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