UCLA Samueli
School of Engineering

ECE 209AS Fall 2020 Bake-off Demo, 10/28/20

HMM-T9: An AI-enabled Tiny T9 Keyboard

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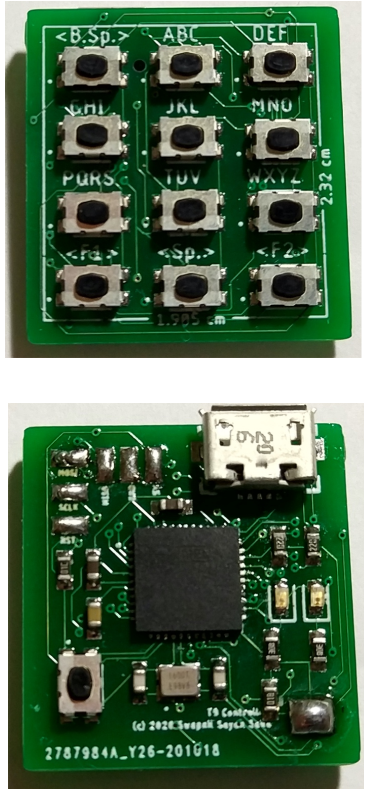
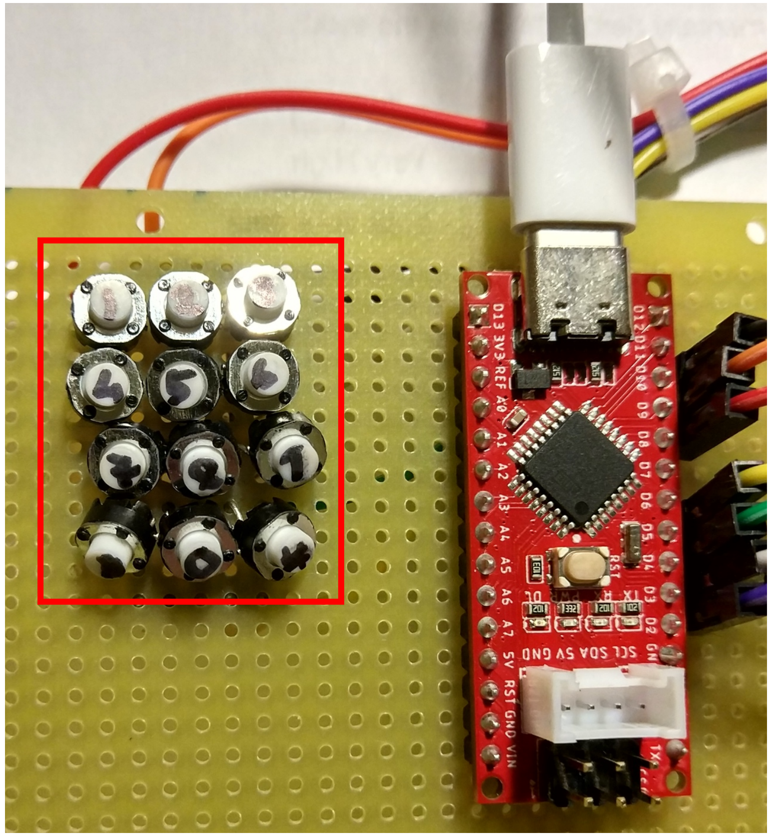
Design Intuition

Natural and adopted layout → Strong feedback → Robust to elements and user changes → Touch-screen independent → AI-enabled



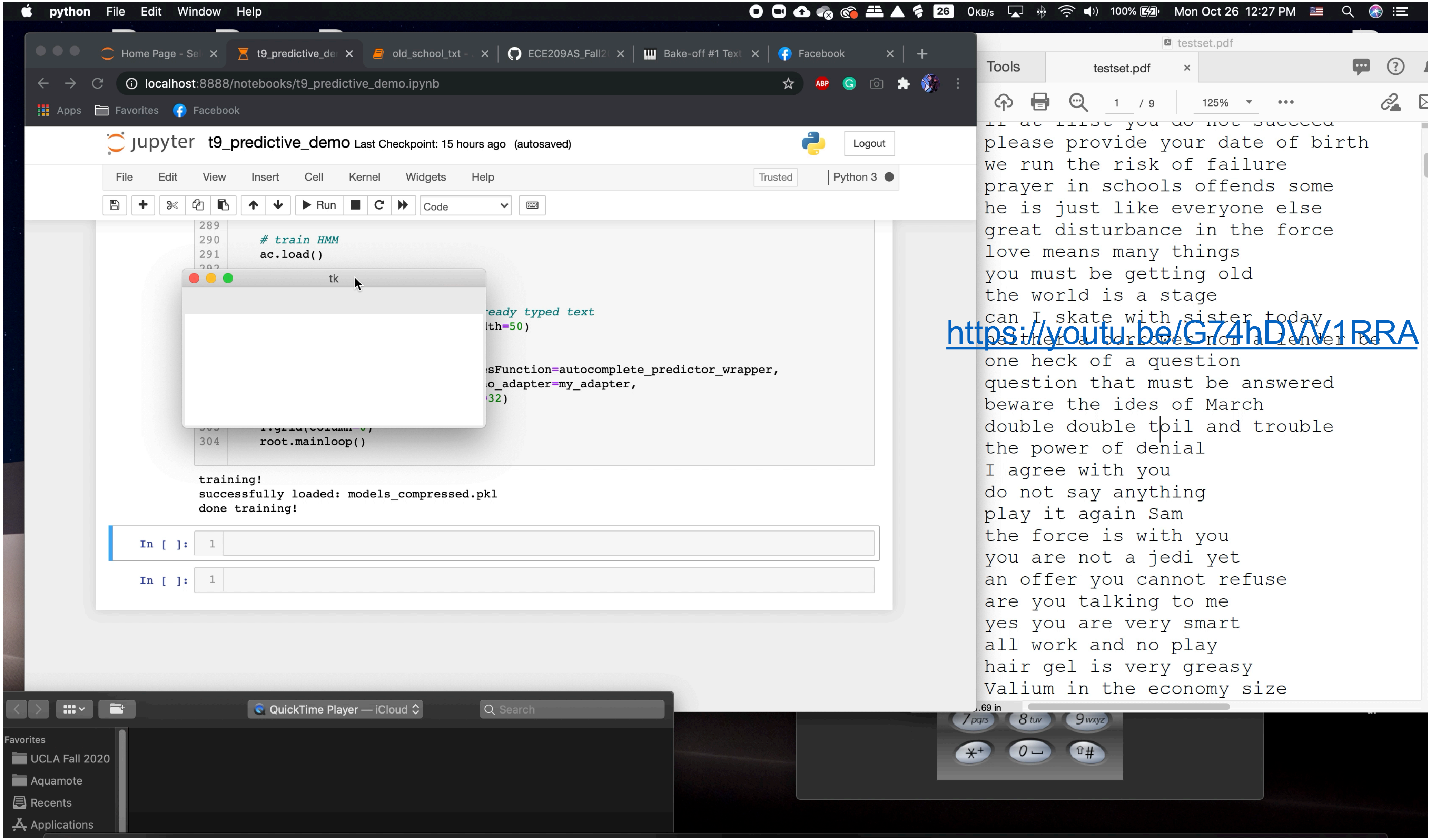
HMM-T9 PCB (fabricated at NESL, UCLA)



HMM-T9 (Veroboard version)

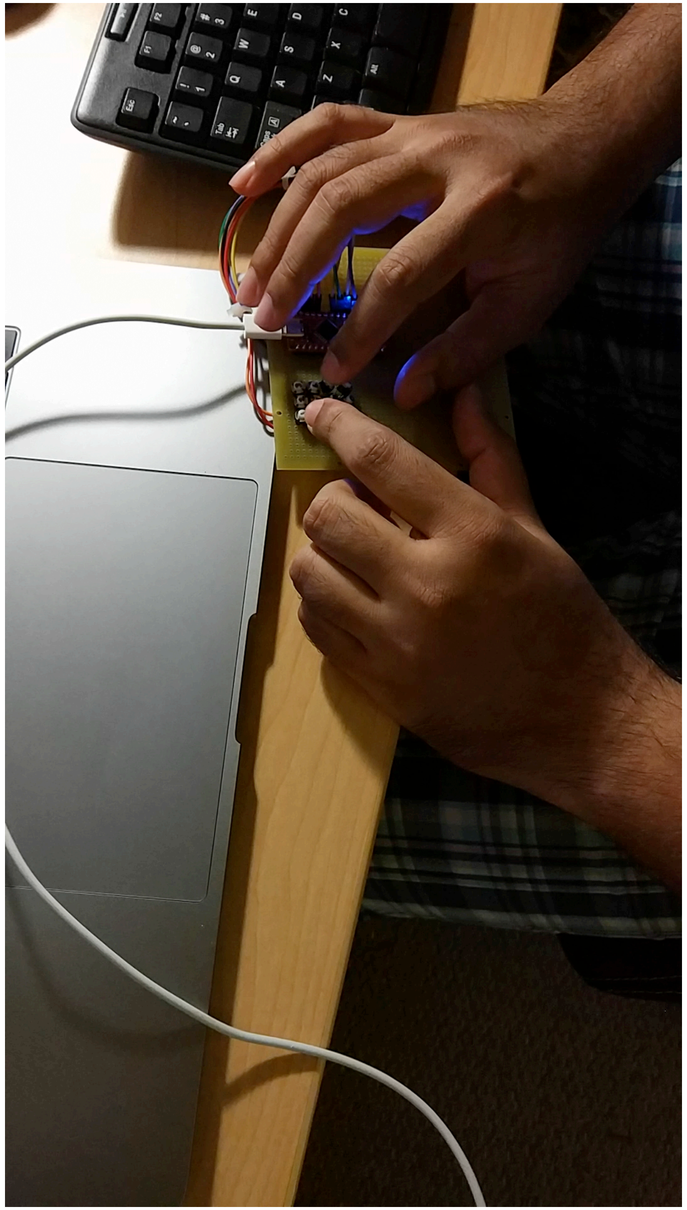
- HMM-T9 – A tiny T9 keyboard using Hidden Markov Models (HMM) for text prediction.
- Contact area: 2.95 cm^2 usable contact area, spread over ~ 2.2 X 1.7 cm (veroboard).
- USB-C communication for broad compatibility spectrum.
- Lightweight-AI assisting familiar layout.

1x Recording



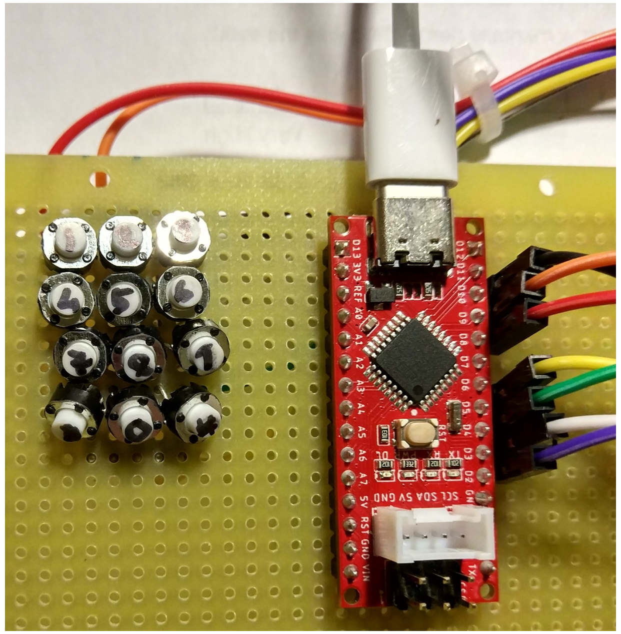
https://youtu.be/G74hDVV1RRA

Demo



https://youtu.be/AMEvziVtORE

Evaluation Criteria



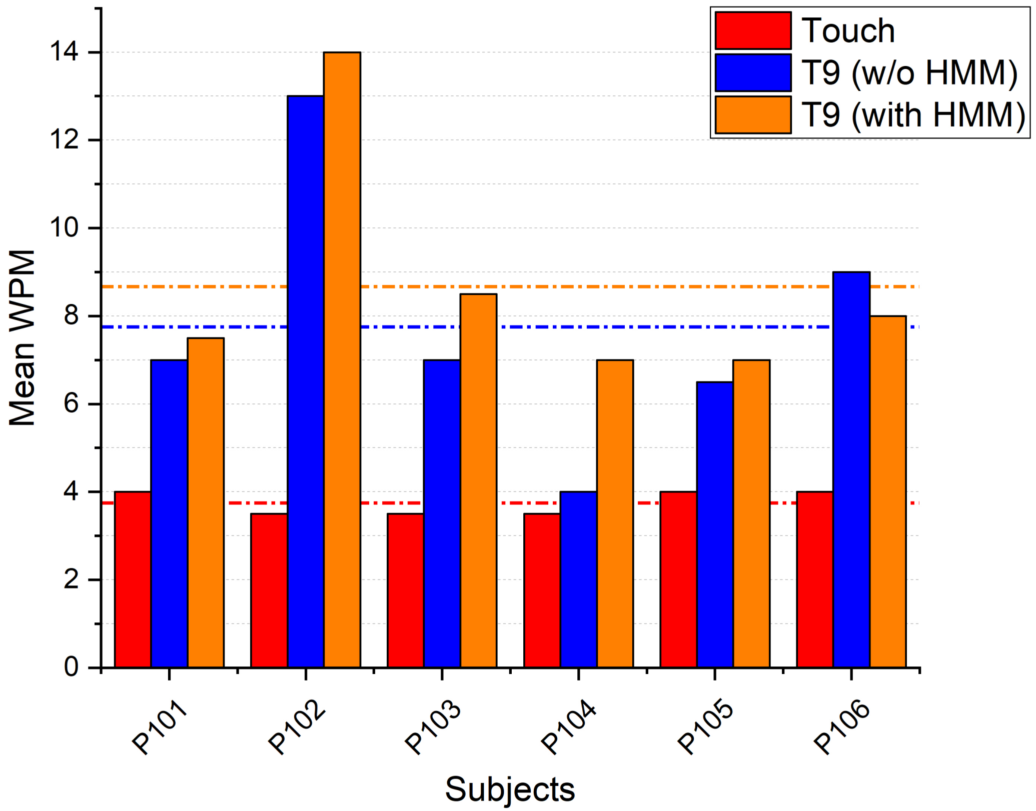
- Three scenarios:
  - Tiny touchscreen keyboard (1.8 X 2.3 cm)
  - HMM-T9 without AI
  - HMM-T9 with AI

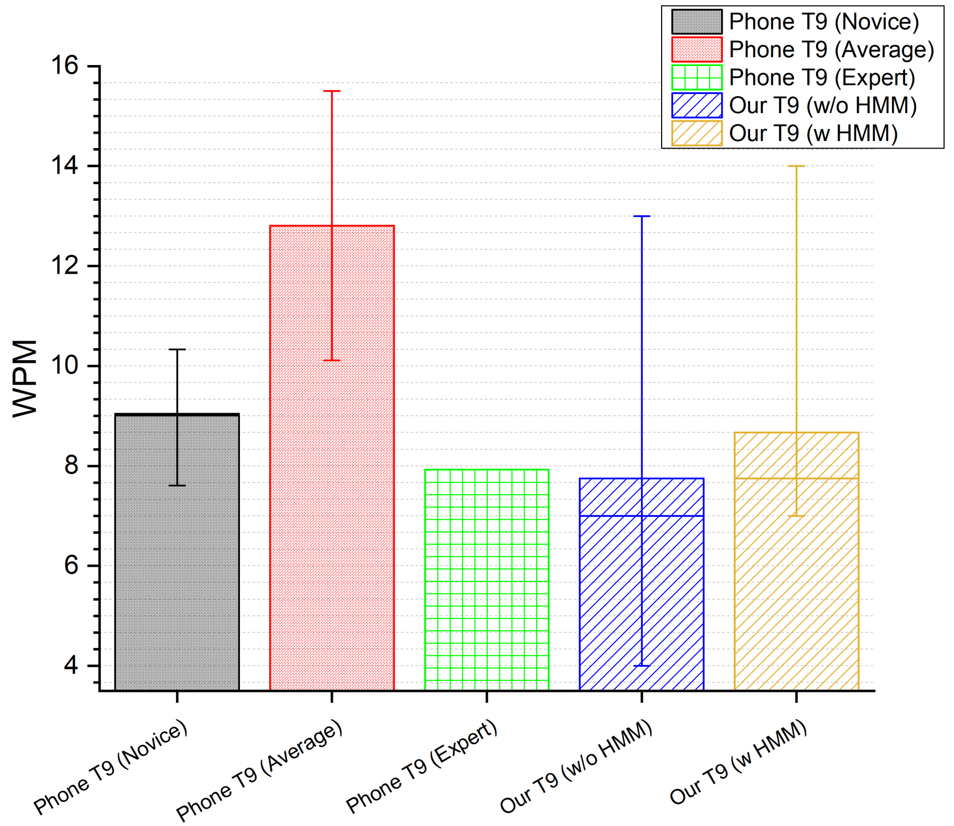
- 6 participants – each type words from the given test set as per their choice for 2-3 minutes.

- Metrics:
  - Performance - Mean WPM (observed + literature);
  - Usability - System Usability Scale (SUS)
  - Workload - Unweighted NASA Task Load Index (TLX)
  - General and suggestive - questionnaire and rubric-based rating

- Statistical tests (Shapiro-Wilk, Friedman and Wilcoxon Signed Rank) to strengthen observed figures.

User Study – WPM and Evidential Proof

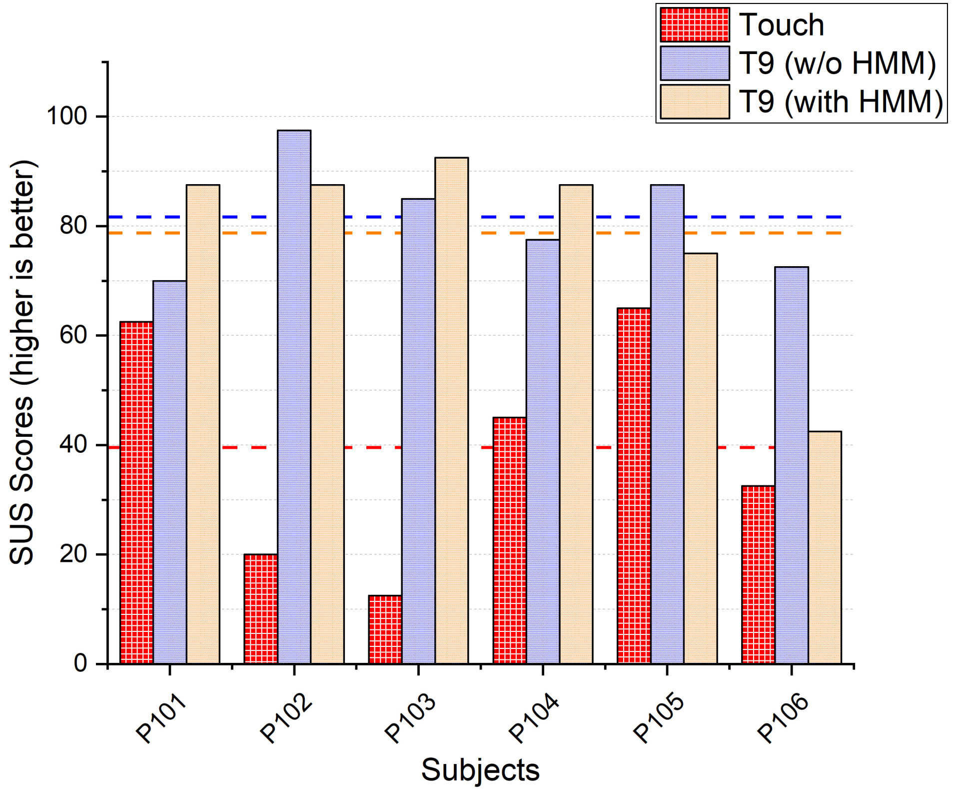


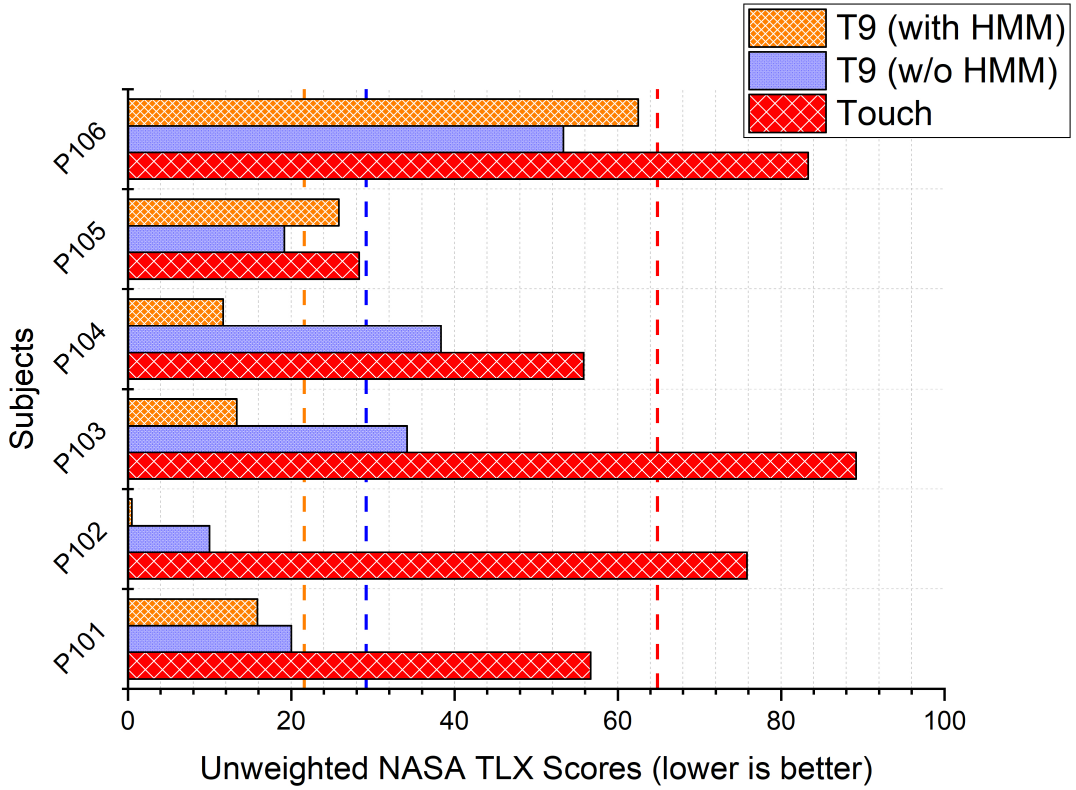


- Shapiro-Wilk test: Gaussian distribution violation in “Touch” and “T9 (with HMM)”.
- Friedman test @ p = 0.05 reveals significant effect of method on WPM ($\chi^2 = 10.33$, $p > \chi^2 = 0.0057$) – **T9 system provides ~ 2x the speed of touchscreen baseline.**
- Friedman test @ p = 0.05 ($\chi^2 = 2.67$, $p > \chi^2 = 0.1025$) and post-hoc Wilcoxon signed ranks test reveals **negligible contribution of HMM on WPM.**
- **Observed WPM (8-9 WPM)** in-line with larger T9 systems [1] - **strong evidence to support observation.**
- **Miniaturized T9 keypad achieves similar WPM to phone T9 systems!**

[1]. Arif, Ahmed Sabbir, and Wolfgang Stuerzlinger. "Analysis of text entry performance metrics." 2009 IEEE Toronto International Conference Science and Technology for Humanity (TIC-STH). IEEE, 2009.

User Study – SUS and TLX Scores

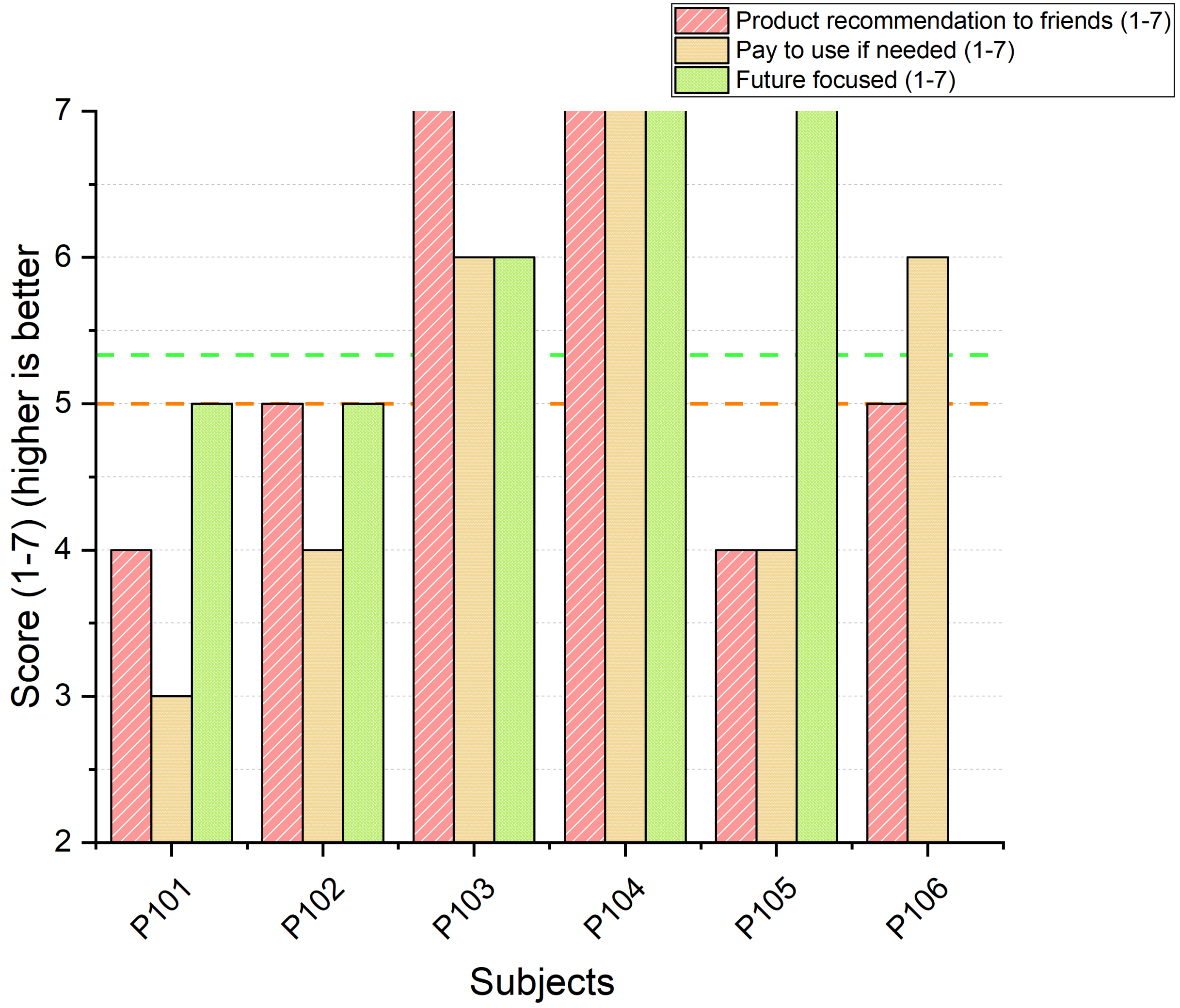




- Shapiro-Wilk test: Gaussian distribution violation only in "T9 (with HMM)" SUS score.
- **Usability grade** [1] - Touchscreen: F**, T9 w/o HMM: A, T9 with HMM: B.**
- **Workload category** [2] **-** Touchscreen: High**, T9: Medium.**
- Friedman test @ p = 0.05 reveals significant effect of method on SUS score ($\chi^2 = 9$, $p > \chi^2 = 0.011$) and TLX rating ($\chi^2 = 9.33$, $p > \chi^2 = 0.0094$) – **T9 system provides ~ 2x the usability and ~0.5x the workload compared to touchscreen baseline.**
- Friedman test @ p = 0.05 ($\chi^2 = 0.2, 0.67$, $p > \chi^2 = 0.65, 0.414$) and post-hoc Wilcoxon signed ranks test reveals **negligible contribution of HMM on SUS score and TLX rating.**

[1]. Sauro, Jeff. "Measuring usability with the system usability scale (SUS)." (2011).
[2]. Prabaswari, Atyanti Dyah, Chancard Basumerda, and Bagus Wahyu Utomo. "The Mental Workload Analysis of Staff in Study Program of Private Educational Organization." IOP Conference Series: Materials Science and Engineering. Vol. 528. No. 1. IOP Publishing, 2019.

User Study – General Feedback



- Shapiro-Wilk test: No statistical bias found in user-rating.
- **Recommendation, pay-to-use and future-usage rating: ~ 5 out of 7**.

Easy and Natural	*"…keypad is clicky and the feedback makes it very easy to know that the key was pressed…"* *"…physical buttons much better than touch keys, clicking is helpful…easier to handle than touch…"* *"…natural layout, easy to learn…"*
Useful and Fast	*"…much faster than touchscreen keys…"* *"…prediction works well sometimes and very useful…"* *"…product can be learned quickly…"* *"…tactile feedback is useful…"*
Novelty	*"…integrating with HMM is novel…"* *"…the predictive word suggestions are novel…"* *"…capability to predict and complete words…"* *"…toggling suggestions with up and down key"*
Usage-scenarios	*"…wearable devices without touch screens, visually impaired people, low-cost fast typing portable keyboard…"* *"…battery constrained edge devices…"* *"…algorithm can be integrated with other devices, system can be used for smaller spaces…"*

User Study – Suggestions

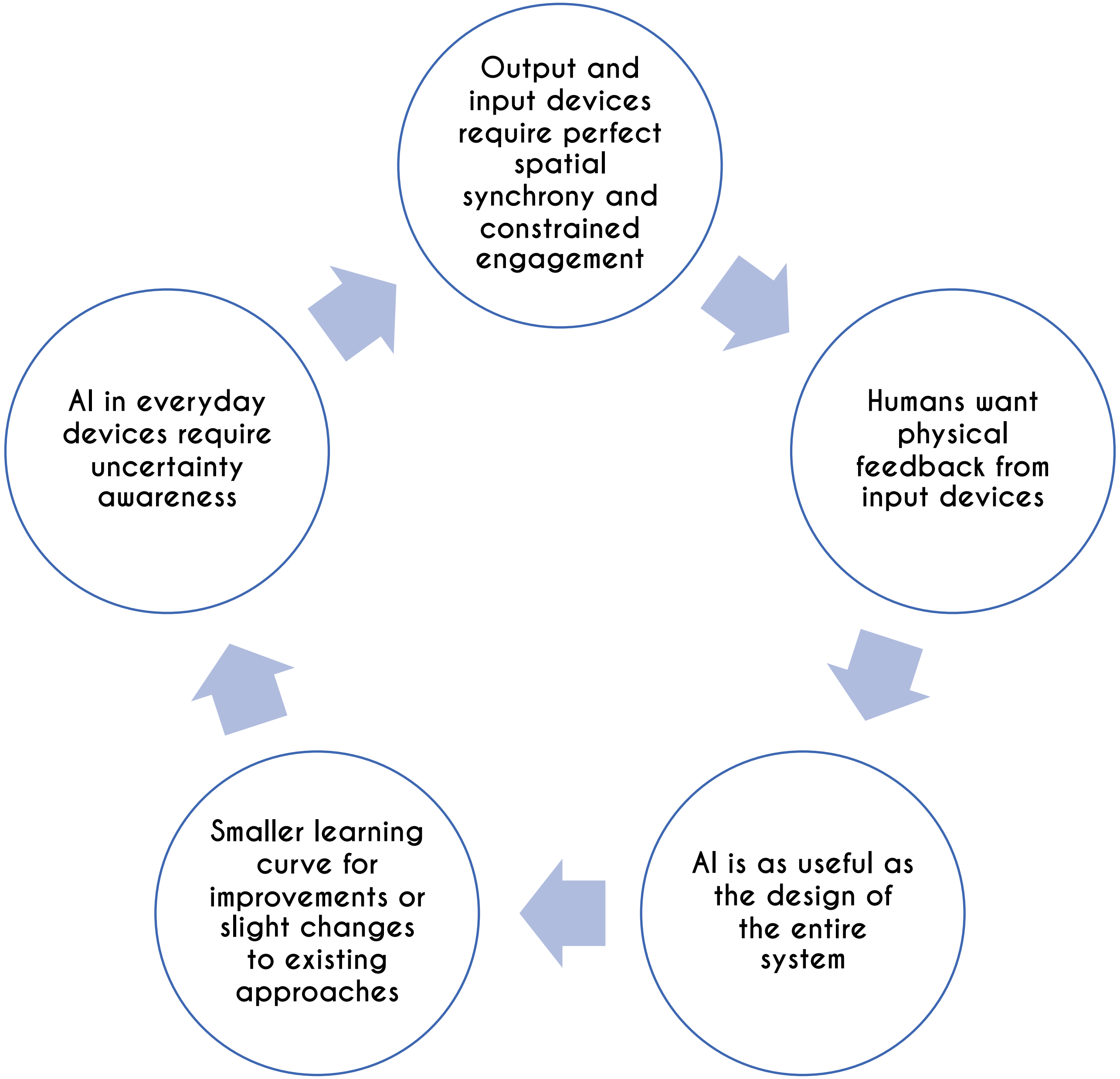
- AI needs further improvement:
  - HMM has no attention model to ignore confounding or erroneous inputs in its history.
  - Trained on small dataset with common words.
  - AI needs to learn context of the user input.

- Keypad and output device need to be closer to each other:
  - Hard to focus on the keypad and the screen simultaneously.
  - Keypad needs to be labelled well.
  - Too much to focus on for the AI-enabled setup (keypad, output, word suggestions, keypad labels)

- **Above points render AI not significantly helpful in our current demo.**

- Fix occasional bugs (e.g. poor handling of wrong inputs and backspace error).

Lessons Learned



Future Work

- Fix bugs in the current model, as well as the PCB.
- Explore sophisticated NLP models with uncertainty handling schemes (e.g. LSTM/RNN based models trained on larger datasets).
- Hardware and driver setup for a tiny OLED display near the keypad, capable of showing output and text predictions.
- On-device edge AI.

THANK YOU

Code, results and hardware fabrication guide available for free at:
https://github.com/swapnilsayansaha/ECE209AS_Fall2020

Contributions:

- Viacheslav Inderiakin: application backend design, prediction algorithm implementation and integration of all the parts.
- Swapnil Sayan Saha: Hardware and driver co-design, application frontend design, experimental studies and general project directions.