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研 究 終 了 報 告 書

「Design Thinking for Facilitating Data Annotation and Machine Learning」

研究期間： 2021 年 10 月～ 2024 年 3 月
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1. 研究のねらい

Data-driven intelligent systems rely heavily on training data and machine learning algorithms. There is a huge demand for improved machine-learning outcomes. One popular approach is the development of better algorithms. The majority of studies concentrate on this aspect. However, an equally essential approach involves enhancing the quality of the data itself. In my ACT-X research project, my focus was on **providing better data**, without increasing costs, to enhance machine learning results.

Manual data annotation is a labor-intensive process often reliant on crowd workers, typically non-experts, which can lead to numerous errors. While spending more money to recruit professional annotators is a common solution, it can become prohibitively expensive, especially when a large volume of training data is required for which no existing datasets exist. The primary objective of this project is to elevate data quality without escalating costs. In other words, I plan to propose more **efficient**, **supportive**, and **learnable** labeling approaches/interfaces for non-expert data annotation (i.e. improve data quality and machine learning results).

- **Efficient:** non-expert annotators can complete a labeling task more quickly
- **Supportive:** non-expert annotators can complete a labeling task more correctly
- **Learnable:** non-expert annotators can have self-learning during annotation

To fulfill these goals, the primary approaches I plan to use are (a) to investigate a deeper understanding of the user (non-expert annotators) and the user activity (manual data annotation), (b) to design various labeling approaches/interfaces which can match the user requirements in different annotation tasks and different data, (c) to quantitatively and qualitatively evaluate the proposed approaches/interfaces and (d) to conduct machine learning experiments to test the collected data via the proposed approaches/interfaces. As an interaction designer, I plan to **bring Design Thinking into Machine Learning**, to explore alternative solutions for machine learning from a human (user) perspective (i.e. cognitive factor) rather than a technology perspective. The research questions in this study are:

- Can the user interface improve label quality without increasing cost?
- Can the user interface increase the efficiency of the annotation process?
- Can the user interface support self-learning during annotation?

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2. 研究成果

（1）概要

The research goal of this ACT-X project is to explore and design effective data annotation tools for machine learning, specifically targeting non-expert data annotators. During the first year, my primary focus was on designing annotation tools tailored for image labeling tasks on desktop computers. Starting from the second year, I transitioned the research focus from images to audio and shifted the platform from desktop computers to mobile devices.

In the first year, I completed two projects: “Labeling Style” and “DualLabel”. In the “Labeling Style” project, I conducted an empirical study to explore the effect of labeling styles (label quickly and label carefully) used in a data annotation process, and then I used the collected data via different labeling styles for machine learning. In the “DualLabel” project, I designed an image labeling tool that allows users to select a second label for an image when facing difficulty in making a single label selection. These two studies were published in the GI 2022.

In the second year, I completed other three projects: “Dynamic Labeling”, “Speed Labeling” and “SyncLabeling”. The “Dynamic Labeling” project was extended from the “Labeling Style” project where I proposed a control system that can analyze annotators’ labeling behaviors and dynamically assign an appropriate labeling style to them. In the “Speed Labeling” project, I proposed an image labeling technique that can increase labeling efficiency, by providing a “non-stop scrolling” feature, based on annotators’ labeling speed. Unfortunately, these two studies were currently rejected by an international conference. In the “SyncLabeling”, I designed an audio annotation tool on a smartphone that allows users to annotate two sounds at the same time using two fingers. The result was published in the MobileHCI 2023.

In addition to the five studies, I also supervised three students' projects which relate to my ACT-X research: “ReRoll Labeling”, “ConfLabeling”, and “Trafne Labeling”. The “ReRoll Labeling” was published in the GI 2023 and the “ConfLabeling”, and “Trafne Labeling” were published in the HCII 2022.

For more information about these projects, please visit the project page at
http://chiamingchang.com/labeling+project.html

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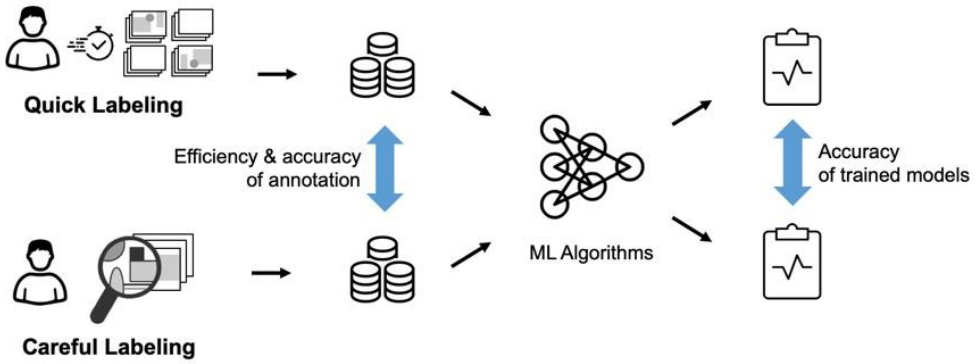
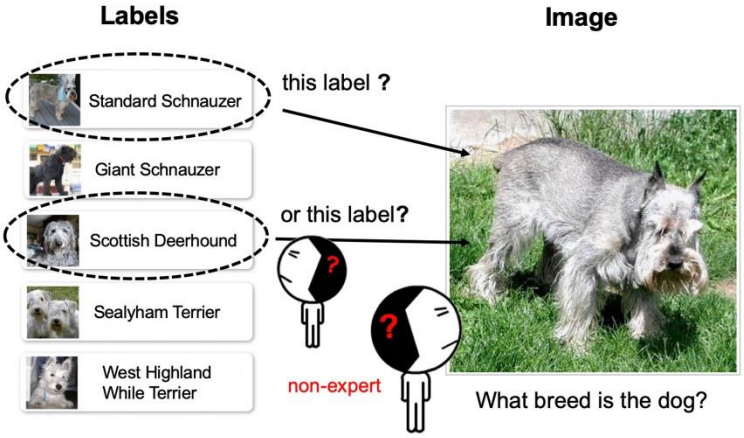
（2）詳細

Project 1: Labeling Style



Assigning a label to difficult data, particularly when non-expert annotators attempt to select the best possible label. However, there have been no detailed studies exploring a label selection style during annotation. This is very important and may affect the efficiency and quality of annotation. In this study, I explored the effects of labeling style on data annotation and machine learning. I conducted an empirical study comparing “quick labeling” and “careful labeling” styles in image-labeling tasks with three levels of difficulty. Additionally, I performed a machine learning experiment using labeled images from the two labeling styles. The results indicated that quick and careful labeling styles have both advantages and disadvantages in terms of annotation efficiency, label quality, and machine learning performance. Specifically, careful labeling improves label accuracy when the task is moderately difficult, whereas it is time-consuming when the task is easy or extremely difficult.

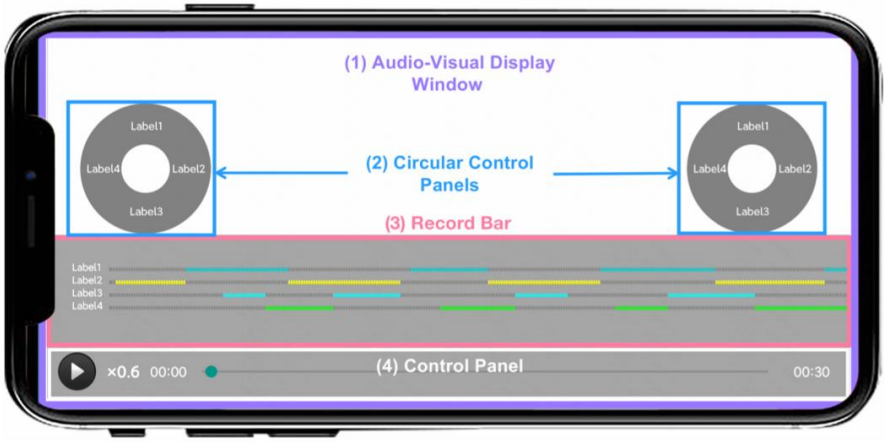
Project 2: DualLabel



Non-expert annotators must select an appropriate label for an image when the annotation task is difficult. Then, it might be easier for an annotator to choose multiple “likely” labels than to select

a single label. Multiple labels might be more informative in the training of a classifier because multiple labels can have the correct one, even when a single label is incorrect. I present DualLabel, an annotation tool that allows annotators to assign secondary labels to an image to simplify the annotation process and improve the classification accuracy of a trained model. A user study compared the proposed dual-label and traditional single-label approaches for an image annotation task. The results show that our dual-label approach reduces task completion time and improves classifier accuracy trained with the given labels.

Project 3: SyncLabeling



Manual audio segmentation is a time-consuming process, especially when there is more than one sound playing simultaneously that needs to be segmented and annotated (e.g., target and background sounds). In conventional audio annotation interfaces, users need to repeatedly pause and replay the audio to complete an overlap segmentation task, which is very inefficient. In this paper, we propose “SyncLabeling,” a synchronized audio segmentation interface for smartphones that allows users to segment and annotate two overlapping sounds in a single audio stream at a time using a game-like labeling interface on mobile devices. We conducted a user study to compare the proposed SyncLabeling interface with a conventional audio annotation interface on four types of audio segmentation tasks. The results showed that the proposed interface is much more efficient than the conventional interface (2.4× faster) under comparable annotation accuracy in most tasks. In addition, more than half of the participants enjoyed using the proposed SyncLabeling interface and showed willingness to use it.

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３．今後の展開

Over the 2.5-year research period, I designed and developed several effective data annotation tools tailored for image and audio annotation tasks. However, these annotation tools were solely prototypes used for user evaluation. To enhance the impact of the ACT-X project, my intention is to further develop these annotation tools into fully functional versions accessible to researchers in the machine learning field. Moreover, this project underscores the significance of the “Design Thinking"’ methodology in addressing technical challenges with a human-centric approach, particularly in defining problems. Moving forward, I aim to consistently apply the design thinking method to diverse research topics.

４．自己評価

As an ACT-X researcher, I've gained extensive insights through the research journey and the events facilitated by JST. Most notably, I've acquired skills in leading research projects, forming and managing small teams comprising students and interns, and fostering collaborations with fellow researchers. I've come to realize that the research process holds greater significance than the outcomes themselves. These learnings and experiences hold immense value for my future endeavors in research. While I've successfully published several papers, I feel the research outcomes might be somewhat inadequate. This sentiment arises because two of my projects (“Dynamic Labeling” and “Speed Labeling”), were rejected by a top-tier international. Nonetheless, I consider this setback a valuable lesson and continue to strive for improvement.

５．主な研究成果リスト

（1）代表的な論文（原著論文）発表

研究期間累積件数：9件

1. **Chia-Ming Chang**, Yi Tang, Xi Yang, Xiang 'Anthony' Chen, and Takeo Igarashi. 2024. Speed Labeling: Non-stop Scrolling for Fast Image Labeling. GI 2024 [paper]
2. Yi Tang, **Chia-Ming Chang**, Xi Yang, and Takeo Igarashi. 2023. SyncLabeling: A Synchronized Audio Segmentation Interface for Mobile Devices. MobileHCI 2023 [paper]
3. **Chia-Ming Chang**, Xi Yang, and Takeo Igarashi. 2022. An Empirical Study on the Effect of Quick and Careful Labeling Styles in Image Annotation. GI 2022 [paper]

（2）特許出願

研究期間全出願件数： 0 件（特許公開前のものも含む）

（3）その他の成果（主要な学会発表、受賞、著作物、プレスリリース等）

- Best Poster Award, Yi Tang, Chia-Ming Chang, Xi Yang, and Takeo Igarashi. A Synchronized Audio Segmentation Tool for Mobile Devices. 3rd International Symposium on Intelligence Design (ISIS2023), University of Fukui (online), Japan, 13-14 March 2023.