（様式5）

|  | 指導教員 承認印 |  |
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# 学位（博士）論文要旨
(Doctoral thesis abstract)

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| 論 文 題 目 (Title) | オンライン手書き数式認識の逐次認識の研究<br>（A study on incremental recognition of online handwritten mathematical expressions) |

論文要旨（2000字程度）
(Abstract(400 words))
※欧文・和文どちらでもよい。但し、和文の場合は英訳を付すこと。
（in English or in Japanese)
（英訳）※和文要旨の場合(400 words)

Handwritten mathematical expressions (MEs) recognition is an area that demands attention due to the rapid growth of touch-based and pen-based devices. This thesis first surveys the methods that have been used recently in recognizing online and offline HMEs. A common way to recognize HMEs is to split the recognition process into four key tasks: symbol segmentation, symbol recognition, spatial relation classification, and structure analysis. This survey classifies methods on each key task and discusses advantages as well as drawbacks of each method. Moreover, we also give an overview of end-to-end approaches that deals with all key tasks at once. The limitation of current works is discussed and the future direction is sought.

The second part is an augmented incremental recognition method (IRM) for online handwritten MEs. The IRM recognizes an ME whenever a new single stroke is input. It shortens the waiting time but degrades the recognition rate due to the limited context. Thus, we propose an augmented IRM that not only maintains the advantage of the two methods but also reduces their weaknesses. The proposed method has two main features, one is to process the latest stroke, and the other is to find the erroneous

segmentations and recognitions in the recent strokes and correct them. In addition, the waiting time is further reduced by employing multi-thread processes. Experiments on our dataset and the CROHME datasets show the effectiveness of this augmented IRM.

The third part presents a user interface and a method to mix text with MEs in a recognition system for handwritten MEs. We introduce a gesture to distinguish text from MEs and allow all the orders of writing gesture symbol with text. As a gesture symbol, we propose a bounding box since it is not in usual math symbols and it is natural for users. We have collected stroke sequences to write text and MEs from ten people and show the recognition method works well and users are more satisfied with the user interface and method than other systems.

We also implement a combination of the IRM and the mix text with MEs recognition system that update the result of text and ME whenever a user writes a new stroke. This online handwritten recognition system integrates the IRM system for text (English and Japanese) into the IRM for MEs. The gesture is an optional feature if the system cannot classify the text and math symbol automatically.