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| （博士課程）  Doctoral Program | | | | | 指導教員承認印欄  Academic Advisor’s Seal | | | | 熊澤逸夫 | | | | | | | | | 印 |
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|  | 東京工業大学長　殿  To the President ,Tokyo Institute of Technology | | | | | 平成 | | 25 | | | 年 | 7 | 月 | | 18 | | 日 |  |
| Date（yymmdd） | | | | | | | | | | | |
|  |  | | 学位申請者  Applicant | | | | | | | | | | | | | | |  |
|  |  | | | 入学年度：  Academic Year of Admission | | | | | | 平成 | | 19 | | 年度入学 | | | |  |
|  |  | | | 研究科：  Graduate School of | | | 総合理工学 | | | | | | | | 研究科 | | |  |
|  |  | | | 専攻：  Department of | | | 物理情報システム | | | | | | | | 専攻 | | |  |
|  |  | | | 学籍番号：  Student ID Number | | | 07D53390 | | | | | | | | | | |  |
|  |  | | | 学生氏名：  Student’s Name | | | Yugov Vsevolod | | | | | | | | | 印  Seal | |  |
|  | **学位申請書**  ＡＣＡＤＥＭＩＣ ＤＥＧＲＥＥ ＡＰＰＬＩＣＡＴＩＯＮ ＦＯＲＭ | | | | | | | | | | | | | | | | |  |
|  | 論文題目  Thesis Title | Online boosting algorithm based on two-phase SVM training and its  application to image processing  （２相SVM学習を用いるオンライン・ブースティングアルゴリズムとその画像処理への応用） | | | | | | | | | | | | | | | |  |
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|  | わたくしはこのたび博士（　学術　）論文の審査を受けたいので、下記書類を添えて提出いたしますのでご審査くださるようお願いいたします。  I hereby request you to review my Academic Thesis　（Original）　along with the documents below in order to have this  Doctor of（Philosophy）Thesis examined.   1. 論文１篇（Ａ４版）（Original Thesis（Ａ４））・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・ ２通 （2copies） 2. 論文の要旨（Thesis Summary ）・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・ ２通 （2copies） 3. 論文の概要（Thesis Abstract ）・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・ １通 （1copy） 4. 論文目録（Thesis contents）・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・ ３通 （3copies） 5. 履歴書（Resume）・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・・ ２通 （2copies） | | | | | | | | | | | | | | | | |  |

備考 博士（　学術　）の括弧内には、博士論文の内容に係る専攻分野の名称（理学・工学・学術・技術経営のいずれか）を指導教員と相談のうえ、記入すること。

Note Fill in the title of your disciplinary field（Science,Engineering,Philosophy or Management of Technology）by mutual consent with your academic advisor.

（博士課程）

Doctoral Program

**論 文 概 要**

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| 専攻：  Department of | 物理情報システム | | 専攻 |  | 申請学位（専攻分野）：  Academic Degree Requested | 博士  Doctor of | (学術） |
| 学籍番号：  Student ID Number | | 07D53390 | |  | 指導教員（主）：  Academic Advisor(main) | 熊澤逸夫 | |
| 学生氏名：  Student’s Name | | Yugov Vsevolod | |  | 指導教員（副）：  Academic Advisor(sub) |  | |

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| 論文題目  Thesis Title | Online boosting algorithm based on two-phase SVM training and its  application to image processing |

概要（和文300字程度又は英文120語程度）

Thesis Abstract（approx.300 Japanese Characters or approx.120 English Words ）

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| We describe and analyze a simple and effective two-step online boosting algorithm that allows us to utilize highly effective stochastic gradient descent based methods developed for online SVM training without the need to fine-tune kernel parameters, and show its efficiency by several experiments. Our method is similar to the AdaBoost in that it trains additional classifiers according to the weights provided by previously trained classifiers, but unlike AdaBoost we utilize hinge loss rather than exponential loss, and modify algorithm for online setting, allowing for varying number of classifiers.  We show the effectiveness of our method by applying it to the task of object tracking on the mobile device (iPhone). In order to achieve the real-time processing speed we furthermore describe a set of compact features in order to fully utilize the parallel processing capabilities of the device GPU. We then show that utilizing our algorithm with such features allows for a high discrimination rate even with a small number of features being utilized. In addition, by observing similarity between our proposed features and binary Ferns we show that our method can be extended to improve discrimination rate provided by other classification schemes. |

（博士課程）

Doctoral Program

**論 文 要 旨**

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| 専攻：  Department of | 物理情報システム | | 専攻 |  | 申請学位（専攻分野）：  Academic Degree Requested | 博士  Doctor of | （学術） |
| 学籍番号：  Student ID Number | | 07D53390 | |  | 指導教員（主）：  Academic Advisor(main) | 熊澤逸夫 | |
| 学生氏名：  Student’s Name | | Yugov Vsevolod | |  | 指導教員（副）：  Academic Advisor(sub) |  | |

要旨（英文800語程度）

Thesis Summary （approx.800 English Words ）

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| The following paragraphs briefly describe the contents of the thesis:” Online boosting algorithm based on two-phase SVM training and its application to image processing”  In the introduction, we briefly state the need and motivation of our research. We describe the current state of the art techniques for the SVM training and boosting, and show some of their drawback that we aim to address by introducing our method. We then briefly outline our algorithm and its relation to the previously described algorithms. We further describe possible applications of our algorithm, particularly in the field of image processing.  In the second chapter, we discuss related works in the field of both online and offline classification, including such well-established algorithms as AdaBoost and SMO for the SVM training, as well as their online extensions. We also include brief overview of the methods developed for specific applications, in particular, real-time object tracking. We show several drawbacks of many online methods, that is, reliance on a large number of simple features which increases the computational and storage cost, and limited number of selected classifiers, limiting flexibility. The classical methods for non-linear classifications, such as kernel based SVM, are more flexible, but suffer from the rapidly increasing number of kernel expansion terms degrading its performance. In comparison, our method combines online SVM training and boosting, resulting in an aggregate classifier which can be calculated with high efficiency and has accuracy similar or higher to that of converged kernel-based SVM. Its efficiency and flexibility allows us to implement it on the mobile device using the parallel processing afforded by the GPU, which is not feasible for most other methods.  In the third chapter, we give a detailed description of our classification method. Our method is based on the previously described online SVM training methods, such as NORMA and Pegasos. These methods are based on the stochastic gradient descent, similar to the well-known backpropagation algorithm. The bounds on the convergence speed on these algorithms are well defined in the corresponding articles. Furthermore, our algorithm utilizes the similarity between linear Support Vector Machines and boosting, and trains a sequence of the linear SVM by substituting AdaBoost greedy algorithm by the online SVM training solution. To further enhance efficiency, each subsequent SVM in the aggregate classifier is trained based on the weights provided by the classification results of a current aggregate classifier. We use the loss function calculated during the training step on the aggregate classifier to reduce computational costs. Several experiments show that using such weighting solution is necessary for increased accuracy. In this chapter, we also give several results of comparison between our algorithm and other similar training techniques, showing that our algorithm outperforms traditional kernel-based algorithms for nonlinear classification, as well as the fact that replacing a greedy algorithm with fully interactive one may give our method better flexibility compared to AdaBoost even in the offline setting.  In the fourth chapter, we describe the application of our method to the object tracking task on the mobile device. Our approach is somewhat similar to the online boosting approach for image tracking, however the while the constraints of the mobile device render such methods impractical, we show how it is possible to get real-time high accuracy tracking solution by applying our method to simplified image features and leveraging the parallel processing on GPU.  There are several difficulties in using mobile device GPU for parallel computations. While the newer mobile devices allow the use of programmable graphics pipeline(specifically, vertex and fragment shaders), they do not allow usage of high-precision textures or multiple outputs. Therefore, the most effective features are such that can fit into a single output (32-bit), which severely limits applications of most features traditionally used for tracking , such as Haar-like features or color histograms. Also, for maximum efficiency the selected features should limit the access to the neighboring texture fragments. For the above reason, we have selected the simplified 4-bin Local Binary patterns histograms, calculated over a fixed area rectangles of 8x8 pixels. Such features have the maximum value well suited to the available accuracy and can be efficiently calculated in just 2 passes with 8 texture accesses each. Experiments to establish the discrimination power of these features show that, with the application of our training method, the accuracy is sufficient for object tracking.  We then note the similarity of the proposed features to the binary Ferns used for keypoint classification. This allows us to show how the proposed method can be used to enhance existing classification methods. By employing boosting properties of Support Vector Machines we develop a method using a combination of SVM and Ferns for texture recognition. The resulting algorithm keeps simplicity and scalability of original Ferns and achieves the increase in accuracy for lower number of features. We then implement the described method on the mobile device under the same hardware limitations as described above. The resulting implementation can achieve real-time processing of 640x480 video feed while maintaining an acceptable degree of accuracy.  The fifth chapter includes evaluation of the performance and computational efficiency of the other algorithms available for both classification and tracking, applied in both the original framework described in the founding papers and the limited resource framework described in our paper. We compare the performance of Pegasos, NORMA and AdaBoost on the selected image features and some publically available datasets that are large enough to validate the usage of the online training methods. We also investigate the implementation of Online boosting algorithm for object tracking, and show that algorithm exhibits significantly lower computational and storage requirements while giving the comparable accuracy.  Finally, the sixth chapter contains the conclusion to our thesis. |

備考 : 論文要旨は、和文2000字と英文300語を1部ずつ提出するか、もしくは英文800語を2部提出してください。

Note : Thesis Summary should be submitted in either a copy of 2000 Japanese Characters and 300 Words (Engｌish) or 2　copies of

800 Words (English).

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| （博士課程）  Doctoral Program |  | 東京工業大学  Tokyo Institute of Technology |

**論 文 目 録**

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| 報告番号：  Report Number | 甲第 |  | 号 |  | 学生氏名：  Student’s Name | Yugov Vsevolod |

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| 論文題目  Thesis Title | |  | | | | | | | | | | １冊（Copy） | | |
| Online boosting algorithm based on two-phase SVM training and its  application to image processing  （２相SVM学習を用いるオンライン・ブースティングアルゴリズムとその画像処理への応用） | | | | | | | | | | | | | | |
| 印刷公表の方法及び時期  Method and Timing of Publication in Print | | | | | | | | | | | | | | |
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| 参考論文  Reference Thesis | | |  | | | | | | | | | 冊（Copy） | | |
|  | | | | | | | | | | | | | | |
| 上記論文の印刷公表の方法及び時期については、本学学位規程第１６条の規定による印刷公表に該当する旨確認する。  I hereby confirm that the Method and Timing of Publication in print of the above mentioned thesis is in conformity with the provisions on Publication in Print provided in Article 16 of the Institute Regulation on　 Academic degrees. | | | | | | | | | | | | | | |
| 平成 | ２４ | | | 年 | 06 | 月 | 07 | 日 |  | | | | | |
| Date（yymmdd） | | | | | | | | | | | | | | |
|  | | | | | | | | | | 審査委員主査：  Chief Examiner | 熊澤逸夫 | | 印  Seal |  |
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備考 1．印刷公表の方法及び時期については、公表予定の場合も記入すること。

2．論文題目が英文の場合は、日本語の訳文を（　　）付して併せて記入すること。

Notes 1．Fill in Method and Time of Publication in Print even if is only provisional.

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| （博士課程）  Doctoral Program |  | 東京工業大学  Tokyo Institute of Technology |

**論 文 目 録**

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| 報告番号：  Report Number | 甲第 |  | 号 |  | 学生氏名：  Student’s Name | Yugov Vsevolod |

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| 論文題目  Thesis Title |  | | １冊（Copy） |
| Online boosting algorithm based on two-phase SVM training and its　application to image processing （２相SVM学習を用いるオンライン・ブースティングアルゴリズムとその画像処理への応用） | | | |
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| 参考論文  Reference Thesis | |  | 冊（Copy） |
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Notes 1．Fill in Method and Time of Publication in Print even if is only provisional.

2．If the Thesis Title is in English , put the Japanese translation in the brackets.

（博士課程）

Doctoral Program

**履 歴 書**

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| 報告番号：  Report Number | 甲第 |  | 号 |  | 学籍番号：  Student ID Number | 07Ｄ53390 |

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| フリガナ  Kana  氏名  Name | ユゴフ　フシェヴォロド  Yugov Vsevolod | | | | | | | | (男)・女  Male / Female |  |
| 生年月日  Date of Birth |  | | 1984 | 年  year | 09 | 月  month | 04 | 日  day | | |
| 国籍・本籍  Nationality | Russia | | | | | | | | | |
| 現住所  Current Address | 神奈川県大和市下鶴間2889－4リレボーＭＩＹＯＳＨＩⅡ，103 | | | | | | | | | |
| 最終学歴  Final Academic History | | 年月日  Date of Completion（yymmdd） | | | | | | | | |
| Obninsk Gymnasium 00/06/05  Obninsk state technical  University for Nuclear  power engineering :  Bachelor course: 04/07/09  Masters course: 06/07/09 | | | | | | | | | | |
| 研究暦  Research Experience | | 年月日  Date（yymmdd） | | | | | | | | |
| Erlangen-Nuremberg University 05/06/01 | | | | | | | | | | |
| 職歴  Work Experience | | 年月日  Date（yymmdd） | | | | | | | | |
| Database programmer,  Obninsk, Signal: 06/08/01-07/03/30  IOS Programmer,  Dico. Co. Ltd. 10/03/01-now | | | | | | | | | | |