Takashi Washio
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New Frontiers in Artificial Intelligence

JSAI 2006 Conference and Workshops
Tokyo, Japan, June 2006
Revised Seleced Papers

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Lecture Notes in Artificial Intelligence 4384

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Preface

The progress in information technology including artificial intelligence (AI) in the last few decades is remarkable, and has attracted many young researchers to this field. This trend is now accelerated along with the recent rapid growth of computer communication networks and the worldwide increase in researchers. In this context, we have observed many outstanding AI studies in Japanese domestic conferences. They have high technical originality, quality and significance. The annual conference of JSAI (Japan Society for Artificial Intelligence) is one of the key and representative domestic meetings in the field of intelligent information technology. Award papers in this conference have an excellent quality of international standards. The annual conference of JSAI also organizes co-located international workshops to provide excellent study reports.

The objectives of this book are to present the award papers of the 20th annual conference of JSAI 2006 and selected papers from the three co-located international workshops and to promote the study exchange among researchers worldwide. Eight papers were awarded among more than 200 presentations in the conference, and 21 papers were selected from a total of 44 presentations in the workshops of Logic and Engineering of Natural Language Semantics 2006 (LENLS 2006), Learning with Logics and Logics for Learning (LLLL 2006) and Risk Mining (RM 2006). The award papers in the 20th annual conference of JSAI 2006 were selected from presentations covering the wide field of artificial intelligence through the processes of candidate recommendations, detailed open discussions and voting by Program Committee members of the conference. The LENLS workshop series is organized under the aim of bringing together researchers working on information structure and/or dynamic semantics for natural language. LENLS 2006 focused on formal pragmatics in particular. The LLLL 2006 workshop was held to bring together researchers who are interested in the areas of machine learning and computational logic, and to have intensive discussions on various relations between the two thereby making their interchange more active. RM 2006 was held with the aim of sharing and comparing experiences on risk mining techniques applied to risk detection, risk clarification and risk utilization in real fields.

We hope this book introduces the excellent Japanese studies on AI to the world and contributes to the growth of the worldwide community of AI researchers.

November 2006 Takashi Washio

Organization and Editorial Board

The award papers were selected by the Program Committee of the annual conference of JSAI (Japan Society for Artificial Intelligence) 2006. The paper selection of each co-located international workshop was made by the Program Committee of each workshop. Upon the decisions of the paper awards and the paper selections, each chapter was edited by the Program Chairs of the 20th annual JSAI conference and the co-located international workshops. The entire contents and structure of the book were managed and edited by the chief editors.

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Part I

Awarded Papers

Overview of Awarded Papers – The 20th Annual Conference of JSAI

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In this chapter, we proudly introduce eight awarded papers, selected from the papers presented in the 20th annual conference of Japan Society for Artificial Intelligence (JSAI2006).

The conference was held at Tower Hall Funabori located in the east part of Tokyo from June 7 until June 9, 2006. 276 papers were presented in about 60 sessions and over 500 people participated in the conference. Sessions vary from the fundamental issues to the state-of-the-art applications. Session for regular papers are as follows; Logic and learning, Reinforcement learning and agent learning, Agent theory, Auction/Game/Economics, Agent learning, Agent planning, Agent simulation and interaction, Genetic algorithm, Image processing, Information extraction and classification, Clustering/self-organization, Classification learning, Text mining, Graph mining, Mining algorithm, Web mining, Pre- and post-processing for data mining, Practices of data mining, Cognitive modeling, Language processing and dialogue, Robot/sensor network, Web information system, Semantic Web, Knowledge modeling and knowledge sharing, Support of knowledge management, knowledge modeling/ontology, Web service, Human interface and communication support, Education support, Learning support environment, and Musical and auditory information processing.

In addition to these sessions, we have organized sessions that include Socio-infomation infrastructure for intelligent support, Even space information support project, Carrier design for researchers, Computing for semantics and understanding, Natural language processing for knowledge-oriented text mining, Language - computer - communication, Experience media, Intercultural collaboration and AI, Data mining for risk information, and Human-agent interaction. The research area covered by these sessions is wider than the other AI conferences such as IJCAI, AAAI, and ECAI. It indicates that Japanese AI community is so active and eager to explore new topics that its topics are expanding beyond the traditional AI areas.

Among them we selected eleven papers as awarded papers. In order to decide award papers, we asked the program committee members and chairs to review the papers. PC members mainly reviewed the papers and the chairs reviewed both the papers and the presentations. It was very competitive result in this year so that we decided to award top eleven papers. Unfortunately the authors of three of eleven papers were reluctant to rewrite their papers in English (the original papers were written in Japanese). As a result, we have eight awarded papers here.

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As well as sessions, the awarded papers varies from the fundamental issues such as the fundamental consideration of data mining (Tsuyoshi Ide) to the state-of-the-art application such as "knowledge globe" (Hideyuki Kubota *et al.*) and discussion support (Hideyuki Tomobe and Katashi Nagao). In particular, the variety of the applications suggest the potential of the AI approach such as bioinformatics (Hiroshi Yamakawa *et al.*) and musical information processing (Keiji Hirata and Satoshi Tojo). Another uniqueness is mixture of different disciplines; from robotics (Masayuki Furuyama *et al.* and Tetsunari Inamura *et al.*) to psychology (Asako Miura *et al.*). AI becomes the "meeting point" for different disciplines.

Finally we would like to thank all the attendees who joined the discussion that contributes selection of the awarded papers.

JSAI2006 Program Committee

Translational Symmetry in Subsequence Time-Series Clustering

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Abstract. We treat the problem of subsequence time-series clustering (STSC) from a group-theoretical perspective. First, we show that the sliding window technique introduces a mathematical artifact to the problem, which we call the pseudo-translational symmetry. Second, we show that the resulting cluster centers are necessarily governed by irreducible representations of the translational group. As a result, the cluster centers necessarily forms sinusoids, almost irrespective of the input time-series data. To the best of the author's knowledge, this is the first work which demonstrates the interesting connection between STSC and group theory.

1 Introduction

Learning representative patterns from time series data is one of the most interesting tasks in data mining. Since the seminal work of Das et al. [1], subsequence time-series clustering (STSC) had enjoyed popularity as the simplest and the most reliable technique of stream mining. In STSC, time series data is represented as a set of subsequence vectors generated using a sliding window (see Fig. 1 (a)), and the generated subsequences are grouped using k-means clustering (Fig. 1 (b)). The cluster centers (the mean vectors of the cluster members) are thought of as representative patterns of the time series.

Currently, however, k-means STSC is considered to make little sense as a pattern discovery technique, since, as first pointed out by Keogh et al. [9], k-means STSC is "meaningless" in that the resultant cluster centers tend to form sinusoidal pseudo-patterns almost independent of the input time series. This *sinusoid effect* proved that even the simplest algorithms such as k-means STSC could be too dangerous to be used unless the mathematical structures are fully understood. We believe that the sinusoid effect raised a question to the general trend in the stream mining community, where seemingly plausible analysis tends to be accepted without theoretical justifications.

In a previous paper [6], we theoretically studied the origin of the sinusoid effect. The original k-means STSC task was reduced to a spectral STSC task, and sinusoidal cluster centers were explicitly obtained by solving an eigen problem. In this paper, we discuss mathematical properties of STSC in more detail. In

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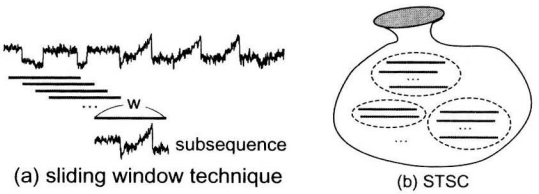

Fig. 1. (a) Sliding window technique to generate subsequences. (b) The generated subsequences are grouped as independent data items.

particular, we will point out that the cluster centers are inevitably governed by irreducible representations of the translational group, because of a hidden translational symmetry introduced by the sliding window technique. To the best of the author's knowledge, this is the first work that points out the interesting connection between STSC and group theory.

The layout of this paper is as follows: In Section 2, we reformulate STSC as the problem of linear algebra in a vector space, and introduce the notion of linear operators. In Section 3, we review the connection between k-means and spectral STSC. In Section 4, we introduce the concept of translational group, and explain its implications in spectral STSC. In Section 5, we derive the solution to spectral STSC from a group-theoretical perspective. In Section 6, we summarize the paper.

2 Lattice Model for Time Series Analysis

In this section, we introduce a lattice model for time series analysis, and show that this model provides us with a very handy way to express the subsequences of time series data. Throughout this paper, we use $\mathbb{R}$ and $\mathbb{C}$ to represent the sets of real and complex numbers, respectively.

2.1 Vector Space in Dirac's Notation

A common approach to express time-series data is to use a scalar function such as $x(t)$. However, this notation is not very effective in describing symmetry properties of the problem. We believe that this has made it difficult to pinpoint the origin of the sinusoid effect. Instead, we introduce a lattice model in Dirac's notation to represent time series data. While Dirac's notation [12,10] is mathematically equivalent to the standard vector-matrix notation, it is much more powerful for describing linear operators, which play an essential role in this paper. In this subsection, we illustrate the notion of Dirac's notation, by following [12].

Let $\mathcal{H}_0$ be a vector space spanned by n linearly independent bases $\{|1\rangle, |2\rangle, ..., |n\rangle\}$. By definition, any vector in $\mathcal{H}_0$ is represented as a linear combination of these bases. For example, a vector $|a\rangle \in \mathcal{H}_0$ may be expressed as