Linking social network analysis with the analytic hierarchy process for visualizing knowledge domains in assessing academic performance – the case of Taiwan’s Intelligent Transportation Systems

Chi-Chung Tao a, Ruei-Jhih Jian b

a,b Tamkang University, Tamsui, New Taipei City 251, Taiwan

a E-mail: cctao@mail.tku.edu.tw

Abstract: This paper introduces empirical studies of visualizing Intelligent Transportation Systems (ITS) knowledge maps and assessing academic achievements. Social network analysis is applied to visualize ITS knowledge maps to quantify the strength of the connections among individuals or universities. The results from empirical study show that development of ITS research is very promising worldwide. CiteSpace and UCINET are proven to be good tools for demonstrating ITS knowledge maps with clusters by subjects, institutions and authors. The Taiwan’s ITS knowledge maps with clusters can be summarized to assess their academic achievements by using AHP analysis. The ranking indicators and corresponding knowledge maps provide an overview of current performance status of ITS researchers in different ITS user services in Taiwan. This can eventually identify the most important ITS user service in local areas, and contribute to highlight hot issues of ITS researches in the future.

Keywords: Intelligent Transportation Systems, Social network analysis, Analytic hierarchy process, Knowledge domains, Academic performance assessment

1. INTRODUCTION

In the age of digital information, the increasing amount of information being generated means that people can access the sources of knowledge from electronic publications, webpages and e-mails over the internet, rather than from traditional paper sources such as books, magazines and newspapers. It creates a new generation to help researchers explore information and transfer into knowledge.

In recent years various information visualization methods were proposed. However it has been neglected to link these methods to the background of researchers and to the knowledge management life cycle. As a result researchers have difficulties to adapt these new methods. The need for knowledge visualization becomes promising because that a mediating framework for the use of visualization methods starting from information exploration and ending with the transfer of knowledge domains is especially helpful for academic researchers.

The primary goal of knowledge visualization is to detect and monitor the evolution of a knowledge domain. More and more researchers in recent years have focused on scientific collaboration networks, such as co-citation networks or social networks of co-authorships. The growing interests in mapping and visualizing the structure and dynamics of specialties is due to the widely accessible bibliographic data sources such as Web of science and Google Scholar (Bar-Ilan, 2008; Meho & Yang, 2007) and freely available web-based special-purpose citation analysis tools such as CiteSpace, and social network analysis (SNA) such as UCINET.

Since 1990s Intelligent Transportation Systems (ITS) becomes a promising research trend in
Taiwan, numerous theses, dissertations and projects increased rapidly. Most of ITS publications are available in Web databases. Academic researchers are, therefore, interested in identifying underlying specialties in ITS field in terms of related universities or groups of researchers by visualization tools. These new techniques can reveal where the most researchable themes in ITS knowledge domain are, and how these major themes associate. Social network analysis is chosen to produce interval/ratio measures of relations among various researchers in ITS knowledge domain to determine the strength of their ties.

In this paper we apply the methods in quantitative studies of science by the visualization software. Our goal is to present both global ITS knowledge maps and domestic ones respectively, and to provide set of cues to facilitate a variety of common tasks in interpretations. Focusing on authors can improve our understanding of the nature of ITS current development status and research fronts.

Although knowledge maps form the big picture to analyze the data and trend, it is still difficult to assess academic achievements due to various types of academic rankings. Our work contributes to quantitative indicator studies of science in two ways: (1) developing a generic indicators by Analytic Hierarchy Process (AHP) to assess individual researcher’s academic achievements in ITS field objectively, and (2) calculating the ratio scores for scholars from different universities to provide an overview of academic achievements in ITS knowledge domain in Taiwan.

2. BACKGROUND

White and McCain (1997) defined five models of literatures: (1) bibliographic, (2) editorial, (3) bibliometric, (4) user, and (5) synthetic. With the computerized tools and techniques available today, the lines between these traditional models can become blurred. In modern visualizations, many user metadata - authors, titles, descriptive terms, dates, etc. - or bibliometric data - citation counts, term distributions, attributes by year, impact factors, etc. These can be easily displayed by visualizations to enhance map interpretations.

This paper conducts the co-citation networks analysis of ITS research based on the data downloaded from the Web of Science at Institute for Scientific Information (ISI), using high-impact international journals as data sources. It illustrates document co-citation networks of the main authors and keyword clusters from ITS field, revealing the topic changes of knowledge structure in different stages of development.

When mapping the structure of science, citation analysis always plays a prominent role. In general, the steps to visualize the knowledge domains include: (1) data extraction, (2) definition of unit of analysis, (3) selection of measures, (4) calculation of similarity between units, (5) ordination or assignment of coordinates to each unit, and (6) results visualization for analysis and interpretation. Steps (4) and (5) are often distilled into one operation which can be described as data layout shown in Figure 1. (Börner, Chen and Boyack, 2003)
The approach in this paper aims at using ITS research literatures from ISI database, then demonstrating how to use CiteSpace software to demonstrate knowledge maps. Except none of Chinese academic publishing is collected by English databases, the shortage of web-based citation databases is not available in Taiwan, an alternative approach to use UCINET is to analyse a variety of local Chinese academic publishing. Our research design can be shown in Figure 2.
3. APPROACH

3.1 Measures and similarity calculation

Citations may be counted and used as a threshold (e.g., only keep the documents that have been cited more than 5 times) in a mapping exercise. Journal impact factors calculated from citation counts are published by ISI, and can be used to enhance visualizations, as can the raw citation counts themselves. Basically, similarity between units is based on citation linkages or co-occurrence similarities. Citation linkage similarities are naturally constrained to use with data derived from citation databases, and the most common co-occurrence similarities include co-term, co-classification, author co-citation, and paper co-citation.

The Vector Space Model (VSM) developed by Gerald Salton (Salton, Yang, & Wong, 1975) is a powerful framework for storing, analyzing, and structuring documents. Originally developed for information retrieval, the VSM is a widely used framework for indexing documents based on term frequencies. Its three stages are document indexing, term weighting, and computation of similarity coefficients.

The discriminative power of a term is determined by the well-known $tf \cdot idf$ model, in which $tf$ denotes the term frequency and $idf$ represents the inverse document frequency. Each document can be represented by an array of terms $T$ and each term is associated with a weight determined by the $tf \cdot idf$ model. In general, the weight of term $T_k$ in document $D_i$ is estimated as follows:

$$
W_{ik} = \frac{tf_{ik} \times \log \left( \frac{N}{n_k} \right)}{\sqrt{\sum_{j=1}^{T} (tf_{ij})^2 \times \log \left( \frac{N}{n_j} \right)^2}}
$$  \hspace{1cm} (1)

where,

$tf_{ik}$ : the number of occurrences of term $T_k$ in $D_i$,

$N$ : the number of documents in a given collection,

$n_k$ : the number of documents containing term $T_k$,

The document similarity is computed as follows based on corresponding vectors $D_i = (w_{i1}, w_{i2}, ..., w_{iT})$ and $D_j = (w_{j1}, w_{j2}, ..., w_{jT})$:

$$
sim_{ij}^{content} = \sum_{k=1}^{T} W_{ik} \times W_{jk}
$$  \hspace{1cm} (2)

Social Network Analysis (SNA) is a strategy for investigating social structures for the situation that there is no effective citation database in Taiwan. According to E. Otte & R. Rousseau (2002), SNA is the mapping and measuring of relationships and flows between people, groups, organizations, computers or other information/knowledge processing entities. Within SNA, there are a variety of strategies used to collect measurements on the relations among the set of actors. The central players are pointed out as are the underlying collaborative relationships between authors. Our SNA using UCINET is performed to describe relationships between scientific authors.
Freeman (1979) defined degree, closeness and betweeness. Degree is the number of ties or neighbors of a node; closeness is the inverse of the sum of all shortest paths to others or the smallest number of ties to go through to reach all others individually; and betweenness is the number of shortest paths on which a node is on.

Degree Centrality:
\[
C_D(n_i) = \sum_j (x_{ij}) = \sum_j (x_{ji})
\]
\[
C'_D(n_i) = \frac{C_D(n_i)}{g - 1}
\]  \hspace{1cm} (3)

where,
- \(x_{ij}\): the actor \(i\) and actor \(j\) co-occurring in the same literature,
- \(g\): the number that actor on the network,

Closeness Centrality:
\[
C_C(n_i) = \left[ \sum_{j=1}^{g} d(n_i, n_j) \right]^{-1}
\]  \hspace{1cm} (4)

where,
- \(d\): the shortest path between the two actor,

Betweenness Centrality:
\[
C_B(n_i) = \sum_{j<k} \frac{g_{jk}(n_i)}{g_{jk}}
\]  \hspace{1cm} (5)

where,
- \(g_{jk}\): the number of geodesics connecting \(jk\),
- \(g_{jk}(n_i)\): the number that actor \(i\) is on,

4. EMPIRICAL STUDIES

4.1 Visualization by Citespace and Ucinet

This paper demonstrates visualization of knowledge maps by Citespace with case studies of Advanced Traffic Management System (ATMS) knowledge domain in Taiwan. We concentrate on topics in land transport and screen related publications manually. First, we identify keywords in the ATMS field for literature searching based on definitions of Taiwan’s Ministry of Transportation and Communication (MOTC). Although we can collect literature information from ISI databases, a manual process is still necessary to identify whether these literature correct or not. The case study in the ATMS field is then provided to illustrate the proposed research design. However, the process of other ITS user services can be done in the same way.

At the beginning, we searched the citation results with keywords in the ATMS field, such as traffic control or traffic management from ISI database. There were 1,274 journal papers between 1990 and 2010 in transportation science & technology discipline. The statistical information show that those papers were cited by 10,034 times and the average citations were
7.8. It means global ATMS knowledge domains increase rapidly and fast. We downloaded all available ATMS publications including title, year, author’s information, abstract, and reference, and using CiteSpace software to illustrate all literature data. CiteSpace can visualize a merged network based on several networks corresponding to snapshots of consecutive years. The merged network characterizes the development of the field over time, showing the most important footprints of the related research activities.

Figure 3 shows that benchmarking countries of journal papers relating to ATMS worldwide. As can be seen in Table 1, USA’s academic achievements in the field of ATMS are remarkable rich, the number of citations are higher than other countries, reaching 522 times. Other countries are England, Canada, China, South Korea, Taiwan, the Netherlands, Greece, and Italy respectively. It is clearly that England has the highest burstness value 5.36 in the field of ATMS, and the centrality is 0.11. It reveals that England has a vital position to connect other country and lots of academic cooperation as well. The linkages of nodes show relationships to publish papers, and the cooperation relationships to publish paper in Europe is close than other countries. In Asia, China and South Korea have some academic achievement performance by themselves.

Table 1: The cited times of author’s country in Global ATMS fields (Cited times > 30times)

<table>
<thead>
<tr>
<th>Country</th>
<th>Cited times</th>
<th>Burstness</th>
<th>Centrality</th>
</tr>
</thead>
<tbody>
<tr>
<td>USA</td>
<td>522</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>ENGLAND</td>
<td>92</td>
<td>5.36</td>
<td>0.11</td>
</tr>
<tr>
<td>CANADA</td>
<td>75</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>CHINA</td>
<td>74</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>SOUTH KOREA</td>
<td>59</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>TAIWAN</td>
<td>43</td>
<td>-</td>
<td>0</td>
</tr>
<tr>
<td>NETHERLANDS</td>
<td>43</td>
<td>3.97</td>
<td>0.04</td>
</tr>
<tr>
<td>GREECE</td>
<td>36</td>
<td>-</td>
<td>0.05</td>
</tr>
<tr>
<td>ITALY</td>
<td>35</td>
<td>4.31</td>
<td>0.02</td>
</tr>
</tbody>
</table>

Figure 3: The knowledge map of author’s country in Global ATMS fields

Figure 4 illustrates different clusters in the field of ATMS worldwide with automatically generated cluster labels. Table 2 shows automatically chosen cluster labels of 4 largest ACA
clusters along with their size. Top-ranked title terms by $tf \cdot idf$ are selected as cluster labels. The largest cluster urban traffic control-system (#35) has 27 members. The second largest cluster (#13), with 11 members, is labeled as area traffic control & assignment. Other candidate labels for the cluster include signal control, confirming that this cluster deals with classic traffic management issues. The third largest cluster (#43) is dynamic network flow approach.

Figure 4: ACA clusters (1990-2010) (CiteSpace parameters: Nodes=270, Edges=345, top N=30, time slice length=2, clusters=58)

Table 2: The 4 largest ACA clusters of a 270-author network (1990-2010)

<table>
<thead>
<tr>
<th>Number</th>
<th>N</th>
<th>Keywords label</th>
<th>Title terms by tf*idf</th>
</tr>
</thead>
<tbody>
<tr>
<td>35</td>
<td>27</td>
<td>urban traffic control-system</td>
<td>10.62</td>
</tr>
<tr>
<td></td>
<td></td>
<td>energy saving</td>
<td>8.57</td>
</tr>
<tr>
<td></td>
<td></td>
<td>transportation management</td>
<td>8.57</td>
</tr>
<tr>
<td>13</td>
<td>11</td>
<td>area traffic control &amp; assignment</td>
<td>5.72</td>
</tr>
<tr>
<td></td>
<td></td>
<td>signal control</td>
<td>4.83</td>
</tr>
<tr>
<td></td>
<td></td>
<td>traffic control</td>
<td>2.70</td>
</tr>
<tr>
<td>43</td>
<td>10</td>
<td>dynamic network flow approach</td>
<td>15.58</td>
</tr>
<tr>
<td></td>
<td></td>
<td>rerouting problem</td>
<td>15.58</td>
</tr>
<tr>
<td></td>
<td></td>
<td>traffic flow management</td>
<td>13.4</td>
</tr>
<tr>
<td>27</td>
<td>9</td>
<td>traffic-responsive ramp control</td>
<td>7.09</td>
</tr>
<tr>
<td></td>
<td></td>
<td>freeway system</td>
<td>5.38</td>
</tr>
<tr>
<td></td>
<td></td>
<td>evaluation</td>
<td>5.09</td>
</tr>
</tbody>
</table>

The DCA network shown in Figure 5 is also generated by CiteSpace. The largest component shown above evidently contains relevant topics such as traffic control system, networks, performance, assignment, traffic accident, driver behavior, and simulation. The results show evidently that traffic flow and risk have become hot issues in the field of ATMS.
On the whole, the integration of ACA and DCA techniques in a unifying framework will enable analysts, researchers, and students to investigate and understand the dynamic interrelationship between an academic field and an inspired research front. By using visualization tools can simplified and reduced operational costs and search time.

In order to understand current research status in ITS knowledge domain in Taiwan, UCINET software is used to classify ITS technology types by fishbone diagrams and to illustrate Taiwan’s ITS knowledge maps. These results are validated by experts, professors, and researchers in government. Figure 6 shows eight hot issues in the field of ATMS including signals automatic control, traffic management/traffic control, dynamic traffic flow prediction, accident management, communication protocol, automatic vehicle location, automatic vehicle identification, automatic vehicle classification.

Since 1990, there are ten universities participated ITS researches in Taiwan. We first search national digital library of theses and dissertations in Taiwan, and then screen out irrelevant ITS technologies manually. There are 690 theses and dissertations after screening. It shows a steady growth in the number of papers published in Taiwan over a period of 22 years. Obviously, the number of papers increases steadily from 1991 to 2000, reaching 7 to 16. Next, the figures for papers fluctuate between 2004 and 2013. The number of papers increases significantly from 16 in 2001 to 43 in 2013. It can be concluded that papers in ITS fields become more popular after 2000, and Figure 7 shows that Taiwan’s government contributes significantly to ITS deployments since 2000.

The ITS knowledge maps by calculating both degree centrality and betweenness centrality from different universities in Taiwan can be shown in Figure 8. In general, betweenness centrality represents importance of linking range of nodes, and degree centrality represents importance position of nodes, and the thickness of lines represents the number of theses.
Figure 6: The fishbone diagrams of topics in the field of ATMS by technologies category

Figure 7: The fishbone diagrams of topics in ITS fields by technologies category
Table 3: The degree centrality and betweenness centrality in colleges in Taiwan (1990-2013)

<table>
<thead>
<tr>
<th>College</th>
<th>Degree Centrality</th>
<th>Betweenness Centrality</th>
</tr>
</thead>
<tbody>
<tr>
<td>National Cheng Kung Univ.</td>
<td>0.421</td>
<td>0.010</td>
</tr>
<tr>
<td>National Taiwan Univ.</td>
<td>0.421</td>
<td>0.010</td>
</tr>
<tr>
<td>Tamkang Univ.</td>
<td>0.474</td>
<td>0.015</td>
</tr>
<tr>
<td>National Chiao Tung Univ.</td>
<td>0.474</td>
<td>0.015</td>
</tr>
<tr>
<td>Feng Chia Univ.</td>
<td>0.474</td>
<td>0.015</td>
</tr>
<tr>
<td>Chung Hua Univ.</td>
<td>0.368</td>
<td>0.007</td>
</tr>
<tr>
<td>National Central Police Univ.</td>
<td>0.316</td>
<td>0.006</td>
</tr>
<tr>
<td>National Kaohsiung First Univ.</td>
<td>0.316</td>
<td>0.006</td>
</tr>
<tr>
<td>National Chiayi Univ.</td>
<td>0.316</td>
<td>0.004</td>
</tr>
<tr>
<td>Kainan Univ.</td>
<td>0.105</td>
<td>0.000</td>
</tr>
</tbody>
</table>

Figure 8: The visualization knowledge map of Taiwan ITS fields by universities

It shows apparently that ATMS, APTS, and ATIS are three main ITS knowledge domain in Taiwan according to thickness of lines among those three fields and universities. In Figure 8, we can see that the size of square nodes represent CVOS and ETC/EPS are bigger than other fields, and almost all universities in Taiwan published papers in these two fields.

Taking Tamkang University as an example we demonstrate how to illustrate the academic performance in specific field from an organizational perspective shown in Figure 9. It is evident that Tamkang University contributes significantly to academic performance in the field of ATMS which can be shown with the biggest square node on the map. For instance, Professor Chee-Chung Tong has made great effort in the field of ATIS, especially route planning and traveler information and behavior research.
Table 4: The degree centrality and betweenness centrality in Tamkang University (1990-2013)

<table>
<thead>
<tr>
<th>Degree Centrality</th>
<th>Betweenness Centrality</th>
</tr>
</thead>
<tbody>
<tr>
<td>Fan, Chun-Hai</td>
<td>0.182</td>
</tr>
<tr>
<td>Tao, Chi-Chung</td>
<td>0.227</td>
</tr>
<tr>
<td>Tong, Chi-Chung</td>
<td>0.182</td>
</tr>
<tr>
<td>Chiou, Hsien-Ming</td>
<td>0.136</td>
</tr>
<tr>
<td>Chang, Sheng-Syong</td>
<td>0.227</td>
</tr>
<tr>
<td>Luo, Siao-Sian</td>
<td>0.227</td>
</tr>
<tr>
<td>Hsu, Chao-Tze</td>
<td>0.045</td>
</tr>
<tr>
<td>Chen, Dun-Ji</td>
<td>0.227</td>
</tr>
<tr>
<td>Liu, Shih-Sien</td>
<td>0.182</td>
</tr>
<tr>
<td>Hu, Shou-Ren</td>
<td>0.091</td>
</tr>
<tr>
<td>Shih, Fong-Yu</td>
<td>0.045</td>
</tr>
<tr>
<td>Chang, Tang-Hsien</td>
<td>0.091</td>
</tr>
<tr>
<td>Chen, Wan-Hui</td>
<td>0.045</td>
</tr>
</tbody>
</table>

Figure 9: The visualization knowledge map of ITS fields in Tamkang University

The details of research topics in ITS fields at Tamkang University are shown in Table 5.

Table 5: ITS research fields and topics from theses in Tamkang University (1990-2013)

<table>
<thead>
<tr>
<th>ITS field</th>
<th>Research topics</th>
<th>number of theses</th>
</tr>
</thead>
<tbody>
<tr>
<td>ATMS</td>
<td>Traffic management/ Traffic control</td>
<td>21</td>
</tr>
<tr>
<td></td>
<td>Automatic Signal Control</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Automatic Vehicle Classification</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Automatic Vehicle Identification</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Incident management</td>
<td>3</td>
</tr>
<tr>
<td>ATIS</td>
<td>Traveler Information</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Path Planning/Driver information</td>
<td>17</td>
</tr>
<tr>
<td>APTS</td>
<td>Dynamic Bus Information System</td>
<td>7</td>
</tr>
<tr>
<td></td>
<td>Intelligent Rail Transportation</td>
<td>3</td>
</tr>
<tr>
<td>ITS field</td>
<td>Research topics</td>
<td>number of theses</td>
</tr>
<tr>
<td>-----------</td>
<td>----------------</td>
<td>------------------</td>
</tr>
<tr>
<td></td>
<td>Public Transportation Operation Management</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Intelligent Bus system</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Bus Priority Signal</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Demand Responsive Bus</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Car-pool Services</td>
<td>1</td>
</tr>
<tr>
<td>ETC/EPS</td>
<td>Electronic Toll Collection</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>IC Smart Card</td>
<td>1</td>
</tr>
<tr>
<td>CVOS</td>
<td>Fleet management system</td>
<td>4</td>
</tr>
<tr>
<td></td>
<td>Taxi management</td>
<td>2</td>
</tr>
<tr>
<td>AVCSS</td>
<td>Driver Simulation</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Intelligent Driver Assistance System</td>
<td>3</td>
</tr>
<tr>
<td></td>
<td>Advanced Intelligent Vehicles</td>
<td>1</td>
</tr>
<tr>
<td>VIPS</td>
<td>The Elderly Travel Demand</td>
<td>8</td>
</tr>
<tr>
<td>EMS</td>
<td>Emergency Notification</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Emergency Vehicle Operations</td>
<td>1</td>
</tr>
<tr>
<td></td>
<td>Dispatching for disaster rescue</td>
<td>2</td>
</tr>
<tr>
<td></td>
<td>Disaster for Traffic Control</td>
<td>3</td>
</tr>
</tbody>
</table>

4.2 The Analytic Hierarchy Process (AHP) & indicators validation

In addition ITS knowledge maps, the aim of this paper is to propose an effective way to assess academic achievements for researchers in Taiwan. Currently, the assessment of academic achievements is generally to use indicators such as the average number of papers, the number of cited times, and the number of journal papers published in SCI/SSCI or EI.

We conduct a questionnaire survey with the AHP method to develop and establish the assessment indicators weightings for calculating Taiwan’s ITS researcher’s academic achievements objectively.

The first step in AHP process is to construct a tree hierarchy to show the goal at the top, then criteria in the second level, and principle in the next level, and then alternatives at the lowest level. In this study, a 1–9 ratio scale is used to compare three alternatives for indicating the strength of their relative preference. The questionnaires are answered by 30 experts from industry, university and government. The final results are shown in Table 6.

<table>
<thead>
<tr>
<th>Priority code</th>
<th>Indicator</th>
<th>Weight</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 A</td>
<td>To receive international academic award</td>
<td>0.319</td>
</tr>
<tr>
<td>2 B</td>
<td>To receive national academic award</td>
<td>0.101</td>
</tr>
<tr>
<td>3 C</td>
<td>The cited times of published papers from international journal (SCI, SSCI, EI)</td>
<td>0.092</td>
</tr>
<tr>
<td>4 D</td>
<td>The number of published papers from international journal (SCI, SSCI, EI)</td>
<td>0.076</td>
</tr>
<tr>
<td>5 E</td>
<td>To receive international academic conference award</td>
<td>0.041</td>
</tr>
<tr>
<td>6 F</td>
<td>To receive national academic conference award</td>
<td>0.037</td>
</tr>
<tr>
<td>7 G</td>
<td>The cited times of published papers from TSSCI</td>
<td>0.035</td>
</tr>
<tr>
<td>8 H</td>
<td>The number of published papers from TSSCI</td>
<td>0.033</td>
</tr>
<tr>
<td>9 I</td>
<td>The number of research creativity award from the national science council in Taiwan</td>
<td>0.032</td>
</tr>
<tr>
<td>10 J</td>
<td>The number of government research</td>
<td>0.026</td>
</tr>
<tr>
<td>Priority</td>
<td>Code</td>
<td>Indicator</td>
</tr>
<tr>
<td>----------</td>
<td>------</td>
<td>---------------------------------------------------------------------------</td>
</tr>
<tr>
<td>11</td>
<td>J</td>
<td>The number of doctoral dissertation</td>
</tr>
<tr>
<td>12</td>
<td>K</td>
<td>The number of technology transfer</td>
</tr>
<tr>
<td>13</td>
<td>L</td>
<td>International industry-university cooperative research project</td>
</tr>
<tr>
<td>14</td>
<td>M</td>
<td>The number of published papers from international journal (not include in SCI, SSCI, EI)</td>
</tr>
<tr>
<td>15</td>
<td>N</td>
<td>The number of English published books</td>
</tr>
<tr>
<td>16</td>
<td>O</td>
<td>The number of published papers from international academic conference</td>
</tr>
<tr>
<td>17</td>
<td>P</td>
<td>The number of master's dissertation from graduate student</td>
</tr>
<tr>
<td>18</td>
<td>Q</td>
<td>The average cited times from doctoral dissertation or master's dissertation</td>
</tr>
<tr>
<td>19</td>
<td>R</td>
<td>National industry-university cooperative research project (with government)</td>
</tr>
<tr>
<td>20</td>
<td>S</td>
<td>The number of published papers from national journal</td>
</tr>
<tr>
<td>21</td>
<td>T</td>
<td>The average cited times from government research</td>
</tr>
<tr>
<td>22</td>
<td>U</td>
<td>National patent</td>
</tr>
<tr>
<td>23</td>
<td>V</td>
<td>National industry-university cooperative research project</td>
</tr>
<tr>
<td>24</td>
<td>X</td>
<td>The number of Chinese published books</td>
</tr>
<tr>
<td>25</td>
<td>Y</td>
<td>The number of published papers from academic conference</td>
</tr>
</tbody>
</table>

Table 7: The total score of indicators priority for Taiwan's ITS researcher academic achievements in the field of ATMS

<table>
<thead>
<tr>
<th>Researchers</th>
<th>Indicators</th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
<th>...</th>
<th>Total Score</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tao, Chi-Chung</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>1</td>
<td>...</td>
<td>0.172</td>
</tr>
<tr>
<td>Tao, Chee-Chung</td>
<td></td>
<td>0</td>
<td>0</td>
<td>3.5</td>
<td>1</td>
<td>...</td>
<td>0.121</td>
</tr>
<tr>
<td>Fan, Chun-Hai</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>...</td>
<td>0.332</td>
</tr>
<tr>
<td>Luo, Shiaw-Shyan</td>
<td></td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>0</td>
<td>...</td>
<td>0.265</td>
</tr>
<tr>
<td>Liu, Shi-Hsien</td>
<td></td>
<td>0</td>
<td>0</td>
<td>2</td>
<td>0</td>
<td>...</td>
<td>0.457</td>
</tr>
</tbody>
</table>

*The score of academic achievement is connected to personal privacy, so we reveal the real score based on agreement from researchers in Tamkang University

Eventually, we illustrate the most active ITS fields in Taiwan, 232 papers from 1990 to 2013 in the field of ATMS by calculating academic achievement indicators shown in Table 7 and to present a variety of clusters in this field. As can be seen in Fig. 10, there are 24 researchers from different universities focusing on 9 topics, such as signal control, travel time estimation, dynamic traffic assignment, vehicle classification, communication system, incident management, ramp-metering control, vehicle detection, and dynamic origin-destination matrices. It can be observed that signal control, communication system, and travel time estimation are vital and hot issues in the field of ATMS in Taiwan.
5. CONCLUSION

ITS has been developed for over 20 years in Taiwan. This paper aims at focusing on Taiwan’s academic achievements in ITS research fields from 1990 - 2013 with the help of visualizing knowledge maps supported by CiteSpace and UCIENT. The results are particularly encouraging because the presence of knowledge maps and the method using AHP to assess academic achievements are useful and can be applied to other science disciplines.

Due to limitation of databases and time for data screening by manual, some important findings are summarized as follows:

1. Based on citation analysis and theory of knowledge visualizing CiteSpace can illustrate co-citation maps in period of time. Clusters of ITS researches can be shown by colors of nodes, as cooperation relationship, cluster of author, cluster of keywords etc. The results of paper publishing on international ITS journals are not significant, and the cited times by journals and amount of cooperative research are also rare. Furthermore, it is difficult to illustrate knowledge maps from Taiwan's researchers because of language weakness in English, Taiwan's researchers are still encouraged to publish related papers on international journals.

2. Due to lack of useful citation databases for ITS knowledge domain in Taiwan, screening publications manual and validating ITS literature by experts are needed. Using UCIENT software the academic performance in term of ITS publications by university include National Taiwan University, National Chiao Tung University, National Cheng Kung University, Tamkang University, Feng Chia University, and Chung Hua University. Most of papers are published in the field of ATMS.

3. The assessment of academic achievements focusing on journal papers is criticized. By calculating real figures with indicators for assessing academic achievement, the proposed method in this study is validated, and successfully to deploy visualization knowledge map of the academic achievement of Taiwan's researchers in the field of ATMS as well. Developing AHP weightings on indicators will enhance the typical way to assess academic achievements. It is expected that other knowledge maps combining with methods like AHP can be applied to different science disciplines with similar process in this paper.
REFERENCES


CiteSpace: Visualizing Patterns and Trends in Scientific Literature, Website: http://cluster.cis.drexel.edu/~cchen/citespace/


National Digital Library of Theses and Dissertations in Taiwan: http://ndltd.ncl.edu.tw/