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#TSYS-2020-0663R1

50 years of International Journal of Systems Science: A review of the past and trends for the future

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Abstract

International Journal of Systems Science (*IJSS*) is an international journal in the fields of Automation & Control Systems, Computer Science, and Operations Research & Management Science. This paper is a celebration of the 50th anniversary of *IJSS*. A Web of Science count of 7,528 documents were derived from 1970 to 2019 as data sources for the bibliometric analysis. First, the fundamental characteristics of the documents were identified from the bibliometric indicators, and features of keywords were revealed over the half century. A timeline and occurrence analyses were conducted via the software tools, through which popular keywords were visualized in different time periods. These were then grouped into four categories by a hierarchical clustering method, and emerging keywords were selected using burst detection analysis. This was followed by the Autoregressive Integrated Moving Average modelling to predict the future research trends in the four clusters as evidenced in the historical data. Documents were discussed in the recent 20 years towards guiding scholars in three aspects, i.e., problems addressed, popular methodologies, and impact in the relevant fields. Finally, a summary of the main findings was given in the conclusions.

Keywords: *International Journal of Systems Science*; bibliometric analysis; hierarchical clustering; Autoregressive Integrated Moving Average model.

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1. Introduction

International Journal of Systems Science (*IJSS*) is an international journal (Print ISSN: 0020-7721; Online ISSN: 1464-5319) dedicated to publishing high quality, rigorously peer reviewed, original papers that contribute to the methodology and practice in emerging systems engineering themes of intelligence, autonomy and complexity, as introduced in the homepage of the journal. It has been indexed and abstracted in more than 20 databases, such as Web of Science (WoS), Scopus, and Inspec. The impact factor of the journal is 2.149 in 2019 by Journal Citation Reports where it is referred to in three categories, i.e., Automation & Control Systems, Computer Science, Theory & Methods, and in Operations Research & Management Science. At present, *IJSS* publishes 16 issues per year by Taylor & Francis. Due to the fact that it was established in 1970, the journal has gone through a long historical evolution, and has published more than 7000 documents that have made contributions to the relevant fields. In addition, 2020 sees it celebrating the 50th anniversary indicative of its long-establishment and influence over academic scholarship. How to use the information of these documents comprehensively is a valuable issue worth thinking about to analyse the evolution of the journal. Since a document contains much detailed information, such as citations, published year, references, author(s), and institution(s), a quantitative and systematical analysis is required to show the characteristics, features of keywords, and relationships of authors, institutions, and countries/regions. Bibliometrics is such a method that has been recognised to be a better statistical analysis of academic literature, as well as a branch of intelligence science. At the same time, the development trend of keywords in the documents is also an important research issue, and an effective prediction could help scholars and journal seize the direction. Time series analysis, as one of the classical prediction methods, is useful to predict the future trend based on the previously observed data, and has been widely applied in various fields because of its effectiveness and convenience. Therefore, a comprehensive bibliometric and time series analysis of *IJSS* from 1970 to 2019 can provide a detailed insight into its role of supporting the academic community.

Recent trends in bibliometric methods have led to a proliferation of studies that reveal the inner structure and characteristics of a given research direction or a certain journal (Shang et

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al., 2015; White, 2018). Bibliometrics is a complex discipline with the extensive combination of philology, information science and statistics, so that it can explore the details of items, like keywords, for a journal or a specific topic (He et al., 2017). For the analysis of the evolution of research topics, bibliometric methods like co-occurrence analysis, burst detection analysis and clustering methods are used to explore the impact of their topics, some examples being the evaluation of the impact of a set of researchers, or the impact of a particular paper. Recent studies with respect to specific application topics have been researched by bibliometric analysis, such as uncertain group decision making (Wang et al., 2020), sustainable energy (Hache & Palle, 2019), and supply chain of renewable energy (Azevedo, 2019) to name a few. On the other hand, a considerable growth of literature has been found in the theme of bibliometric analysis for journals in an effort to better describe the features and trends for scholars. Studies over the past several years have provided important information on bibliometric analysis for journals, such as the *European Journal of Operational Research* (Laengle et al., 2017), *Economic Research- Ekonomska Istraživanja* (Wang et al., 2020), *IEEE Transactions on Fuzzy Systems* (Yu et al., 2018) and *Technological and Economic Development of Economy* (Yu et al.,2019) amongst others. Along with the continuous development of time series analysis, traditional methods and theories have been improved in the bibliometric analysis to a large extent. Time series analysis has evolved from the study of stationary time series (Whittle, 1953) to increased number of studies exploring non-stationary time series modelling (Hamilton, 1989; Molenaar et al., 1992; Zurbenko, 1991). For bibliometric analysis particularly, time series methods, such as Autoregressive Integrated Moving Average (ARIMA) (Contreras, 2003), Prophet (Samal et al., 2019) and Hot-winters (Roberts, 1982), have proved their relevance and validity in predicting the future evolution of journal indicators (Humphrey et al., 2019; Liu & Rousseau, 2008; Bjork et al., 2013).

The purpose of this paper is to provide a bibliometric and time series analysis of the documents published in *IJSS* from 1970 to 2019, recognizing that it has undergone a half a century of development, and established a position of influence in three subject areas as described above. The main contributions of this paper are as follows: (1) Fundamental characteristics of publications in the *IJSS* are analyzed by bibliometric indicators to describe the detailed structure and the development trend of the journal, including the type, annual trends

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and impact of publications, as well as the geographic distribution of countries/regions of the authors of contributions. (2) Keywords features of documents over the 50 years is presented using bibliometric analysis and muti-variate statistical methods. Specifically, co-occurrence and time line analyses of keywords are carried out using visualization tools (VoS view and CiteSpace) that reveals the relationships amongst keywords. Hierarchical clustering method is also deployed in the clustering of keywords to identify groups that are coherent scientifically and rationally. (3) The tends of keywords in each group are predicted by the ARIMA model with a view to project the possible hot topics or research directions in the relevant fields. (4) Research in the most recent 20 years are summarized as potential research areas that scholars may find useful in their own research pursuits. Further discussions are provided on the problems addressed, popular methodologies, and impact in the subject areas as found in the bibliometric analysis of the journal.

The rest of this paper is organized as follows: Section 2 illustrates the used materials and methods including data sources and specific methodologies. In Section 3, the results are presented based on bibliometric analysis and multi-variate statistical methods, in the form of fundamental characteristics, keywords feature and prediction of future research trends. Section 4 summarizes the current research and provides a contextual discussion. Section 5 concludes the paper with a summary of the main findings.

2. Materials and methods

To review the *IJSS* comprehensively from a historical perspective of its development, reliable materials and methods including bibliometrics and time series analysis were collected and identified. An empirical quantitative research framework was designed, and is shown in Figure 1.

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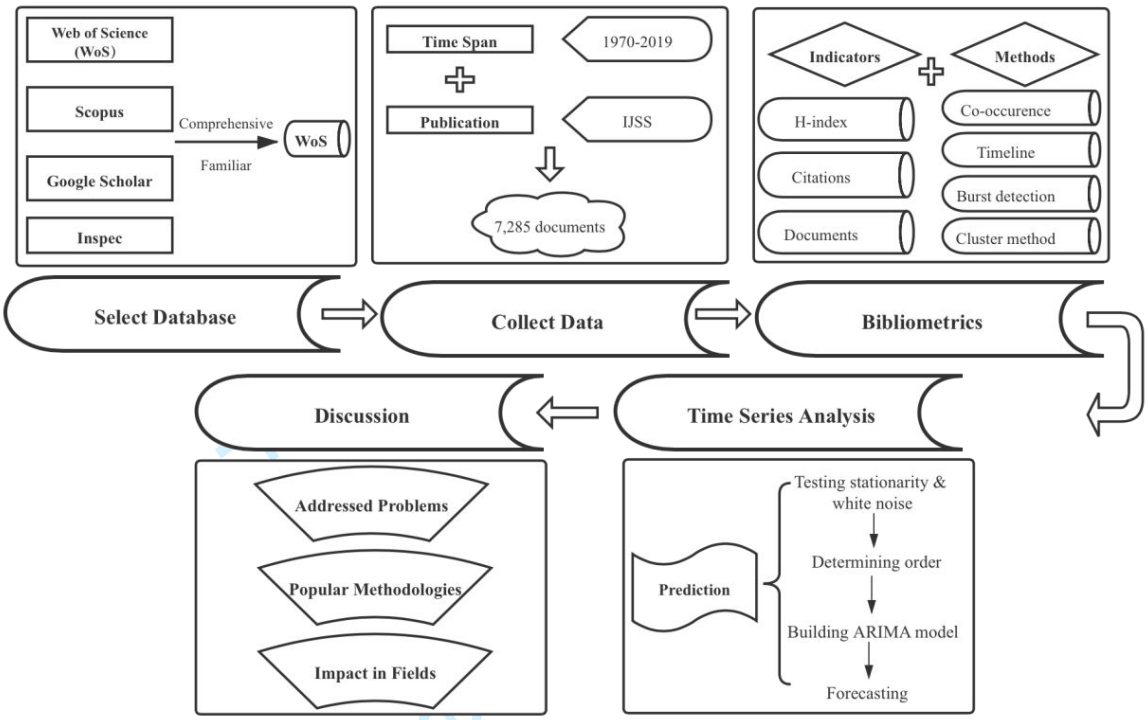

Figure 1. The research framework and process of this study. It is formed of the stages: Scope, data sources, bibliometric analysis, time course modelling and analysis of results.

2.1 Scope and data sources

From the first document written by B. Porter (Porter, 1970) was published in *IJSS* in 1970, all papers published in the journal up to the end of 2019 are included in our comprehensive overview of the journal. We collected data sources from Web of Science (WoS), owned by the company Thomson & Reuters Corporation. WoS is one of the widely used databases in academia (Falagas, 2008), and offers information on leading journals suitable for bibliometric analysis through its details on publications (Cortes-Sanchez, 2019). WoS contains multiple databases, including WoS Core Collection, Derwent Innovations Index, Inspec, KCI-Korean Journal Database, Medline, Russian Science Citation Index and SciELO Citation Index. Through the search function in WoS, and selecting: Publication name= International Journal of Systems Science; Timespan=1970-2019; data; Database= All databases, 7,528 documents were retrieved and selected for the bibliometric analysis. To analyze these documents, we exported them in plain text and Comma-Separated Values (CSV) file formats. This permits detailed and representative perspectives information of documents to be derived, such as title, abstract, keywords, and references.

For the keywords' analysis, the correlation matrix is utilised for the quantification of the

correlation between keywords with frequencies calculated based on the co-word matrix. The elements in the matrix are also called Ochiai correlation coefficient, and computed as (Jackson, et al., 1989):

$$O_{ij} = \frac{A_{ij}}{\sqrt{A_i A_j}} \quad (1)$$

where O_{ij} ranges from 0 and 1, reflecting the probability that the keywords W_i and W_j appear together; A_{ij} is the frequency of keywords W_i and W_j appearing together in all documents, while A_i are the frequency of keywords W_i appearing in all documents.

In the correlation matrix, each element can also be viewed as representing a measure of the distance between two keywords. The larger the value of correlation is and closer it is to 1, the smaller is the distance between two keywords. The smaller the correlation value, however, and closer it is to 0, the farther is the distance between the two keywords.

2.2 Bibliometric analysis

Bibliometrics of research literature is a mature and popular method to highlight the main features in the literature and to evaluate their scientific contributions in a structured way (Liu et al., 2014; Mourao & Martinho, 2020). The bibliometric analysis carried out in this paper is divided into two parts: The first is focused on bibliometric indicators that reveal the characteristics of the *IJSS* publications, and the second uses bibliometric methods and visualization tools based on scientific mapping to chart the journal evolution and the detailed structure of research contributions in the documents.

Some accepted bibliometric indicators have been used to evaluate the influence and productivity of documents scientifically. Several common and recognized indicators were chosen to analyze the feature of documents in the *IJSS*, which include, the H-index (Hirsch, 2005), the number of documents (ND), the number of citations (NC) and the average citations per document (AC). Specifically, the H-index can be used for documents, countries, institutions and authors considering ND and NC, and can express documents' quality, effectively excluding self-citations. The results are dependent on the specific used indicator, and researchers may interpret the result according to their requirements or interests (Hsieh & Chang, 2009).

In general, bibliometric methods extract features of documents by integrating various information, including keywords, references, and other items (country, institution and author).

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To present hot keywords and valuable references over a certain time period, the following classical methods are chosen: (1) Co-occurrence analysis: This is a direct way to highlight the number of keywords that occur together amongst the documents, and the total strength of a keyword reveals the degree of correlation between it and other keywords. Therefore, it also forms the basis for the clustering analysis that follows it. (2) Timeline analysis: By choosing the analysis over different time slices, the underlying trends in keywords in documents published in the journal can be presented in a way that teases out the hot topics and research directions over time periods of interest. (3) Burst detection analysis: Combined with citations and time points, this can identify the emerging trends and most popular items (references/sources/authors) as identified by scholars. Visualisation of the results of the above-mentioned methods by the science mapping tools provides an intuitive structure and the trend of a research subject or of a journal from bibliometric analysis (Cobo et al., 2011). (4) Hierarchical clustering method: This is a common method used for cluster analysis, which also gives flexibility as a result of the variety of approaches it uses for calculating distance, including single, complete and average linkages. In this paper, CiteSpace (Chen, 2006) and VoS viewer (Stopar & Bartol, 2019) are used to provide the visualisation results because of their powerful graphical user interface and applicability in various fields (Heersmink et al., 2011; Pinto, 2015; Niazi & Hussain, 2011).

2.3 Time series analysis

A time series is a sequence of the ordered points over a specific time interval. It has been widely used in statistics, signal processing, pattern recognition, weather forecasting, and largely in any domain of applied science and engineering with temporal measurements. Time series analysis comprises applying methods to time series to extract meaningful statistics and other characteristics of data and using models to predict future value based on previously observed values. Autoregressive Integrated Moving Average (ARIMA) model is one of the most commonly used models to make prediction in the time series analysis. It predicts future values in the short term based on the past observed data in the time series. An ARIMA model is composed of three components, namely Auto Regression (AR), Integration (I), and Moving Average (MA). Each component is denoted by the model order parameters p, d, q respectively and the model is referred to as $ARIMA(p, d, q)$. Assume that Y_t is the value of the

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time series at time t. The p-order auto regression process could be expressed as:

$$Y_t = \alpha + \phi_1 Y_{t-1} + \phi_2 Y_{t-2} + \cdots + \phi_p Y_{p-2} + \varepsilon_t \quad (2)$$

where α is a constant and ε_t is a white noise whose mean value is zero and variance is σ^2.

Time series at time t for the q-th degree of MA(q) is shown as:

$$Y_t = \beta + \varepsilon_t + \theta_1 \varepsilon_{t-2} + \cdots + \theta_q \varepsilon_{t-q} \quad (3)$$

Moreover, if the time series is non-stationary, it can be made stationary by differencing the data d times. By integrating these parameters together, the $ARIMA(p,d,q)$ model is expressed as

$$(1 - \phi_1 L^1 - \phi_2 L^2 - \cdots - \phi_q L^q)\nabla^d Y_t = c + \varepsilon_t + \theta_1 \varepsilon_{t-1} + \theta_2 \varepsilon_{t-2} + \cdots + \theta_q \varepsilon_{t-q} \quad (4)$$

by which $\nabla^d Y_t$ is the variance of Y_t by differencing the data d times, where L^s is a function of backshift operator Y_t, denoted as: $L^s(Y_t) = Y_{t-s}\,(s = 1, 2, \cdots, q)$.

Partial Auto Correlation function (PACF) is utilised in determining the order of AR, and Auto Correlation (ACF) used to find the parameter of the MA model. Akaike Information Criterion (AIC) is usually considered in the determination of the optimal model structure, to obtain the most appropriate orders of the model. The AIC is computed as:

$$AIC = -2\ln(L) + 2k \quad (5)$$

where k is the number of parameters, and L is the likelihood of the data.

3. Results

A thorough and critical review of the published *IJSS* documents from 1970 to 2019 were analysed using the methods described in Section 2 and with a view to presenting the fundamental characteristics of documents, keywords features and trends of future research directions.

3.1 Fundamental characteristics

In the Web of Science (WoS), there are in total 8 types among the 7,528 documents published in the *IJSS* over the past 50 years period from 1970. Amongst these documents, original articles take up a large proportion with 97.53%, followed by editorials (0.72%), meetings (0.52%), corrections (0.42%), letters (0.41%), reviews (0.21%), early access documents (0.17%) and other (0.01%), as shown in Figure 2. It shows the vitality of the journal

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in attracting documents of original research in the main.

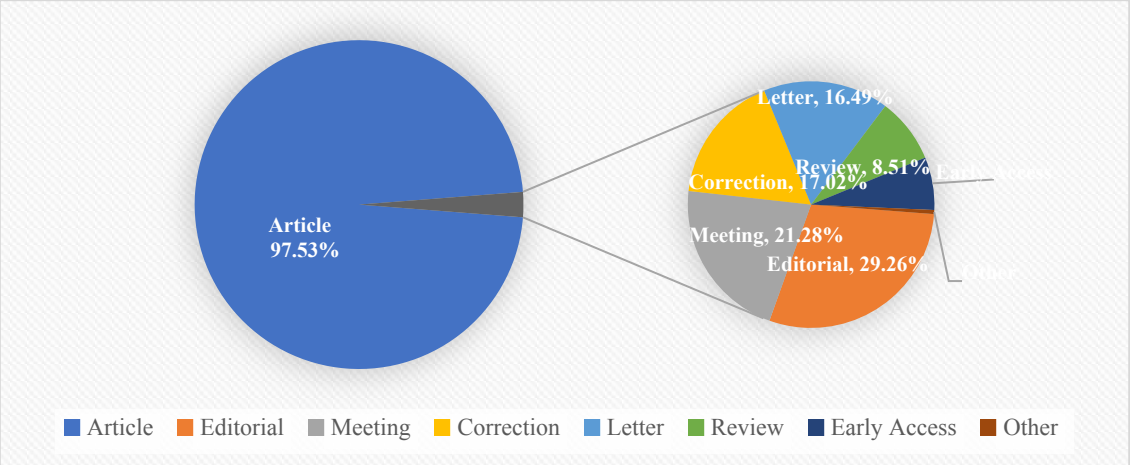

Figure 2. The type distribution of documents in *IJSS* from 1970 to 2019.

Figure 3 shows the trends of the number of documents (ND) and the number of citations (NC) in the journal over 50 years. In Figure 3 (a), it can be seen that, ND goes through two stages of increased phases, i.e., from 1970 to 1991, from 2004 to 2016, respectively. In the first 22 years, ND presents a smooth and slow upward trend, and it levels off at about 100 from 1974 to 1984. Later, it shows a downward trend from 1991 to 2004, and then enters the second ascending stage, and reaches the maximum value with 351 in 2016. In Figure 3 (b), NC presents an increasing trend but with higher volatility in the past 50 years, and there are four obvious peaks in 1978 (2053), 1996 (1984), 2000 (2414), and 2016 (3618), respectively, indicating that documents published in these years have strong following. The falloff of citations since 2016 is influenced by the immediacy and the time delay usually incurred on recently published documents to be widely read, recognized and cited (Pilkington & Meredith, 2009). Combining the development trends of ND and NC, *IJSS* focuses on the quality of manuscripts, and controls the ND to a certain extent. In addition, with the increased citations in recent years, more scholars appear to follow the publications of the journal.

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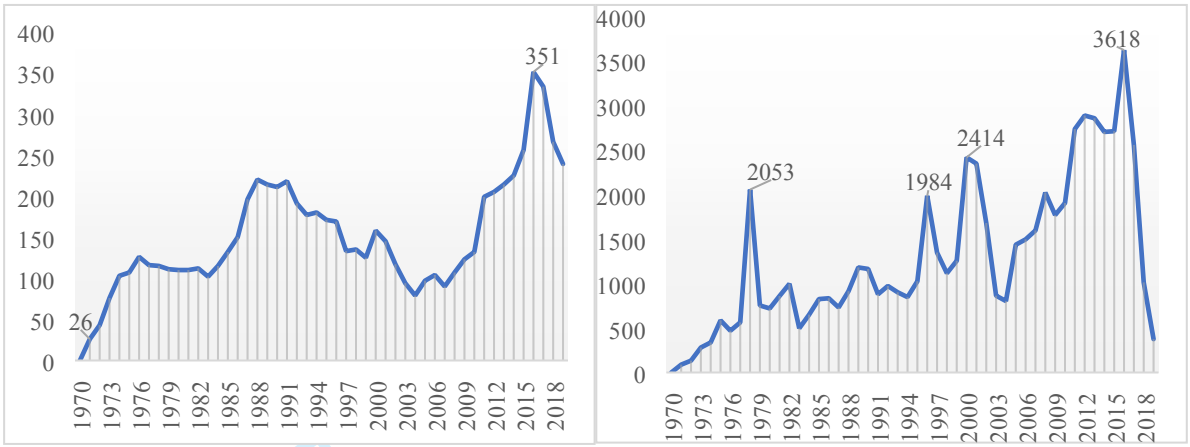

(a) The number of document-year distribution. (b) The number of citation-year distribution.

Figure 3. The number of documents and citations from 1970 to 2019.

The average citations per document (AC) and H-index indicate the influence and recognition of documents in the journal. Figure 4 shows their trends from 1970 to 2019. The AC was smaller than 10 during the first 16 years except for 1978, and then was almost larger than 10 until 2016. This implies that the documents have attracted scholars' attention in recent years. The highest AC is 18.87 in 2008, followed by 17.85 in 1978 and 16.17 in 2001, pointing to the existence of important and popular documents in the issues from these years. The H-index has an upward trend on the whole except for the recent three years. The highest H-index appears in 2000, 2011 and 2012, indicative of the greater productivity and citation impact of the published work of these years, followed by 2013 (26), 2014 (25) and 2016 (25). The AC and H-index trends are almost similar, while the changes are smaller in the H-index than in the AC. Generally, the documents in the recent 20 years have been more recognised and cited than the first 30 years.

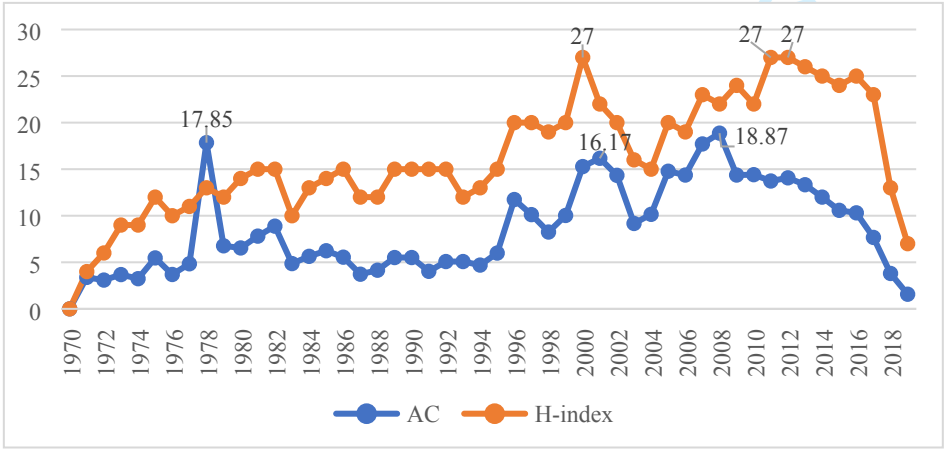

Figure 4. The trends of AC and H-index from 1970 to 2019.

The authors of documents in the journal span 88 countries/regions around the world, and Figure 5 gives the global geographic distribution that covers the six continents, namely Europe, Asia, Africa, Oceania and South and North Americas.

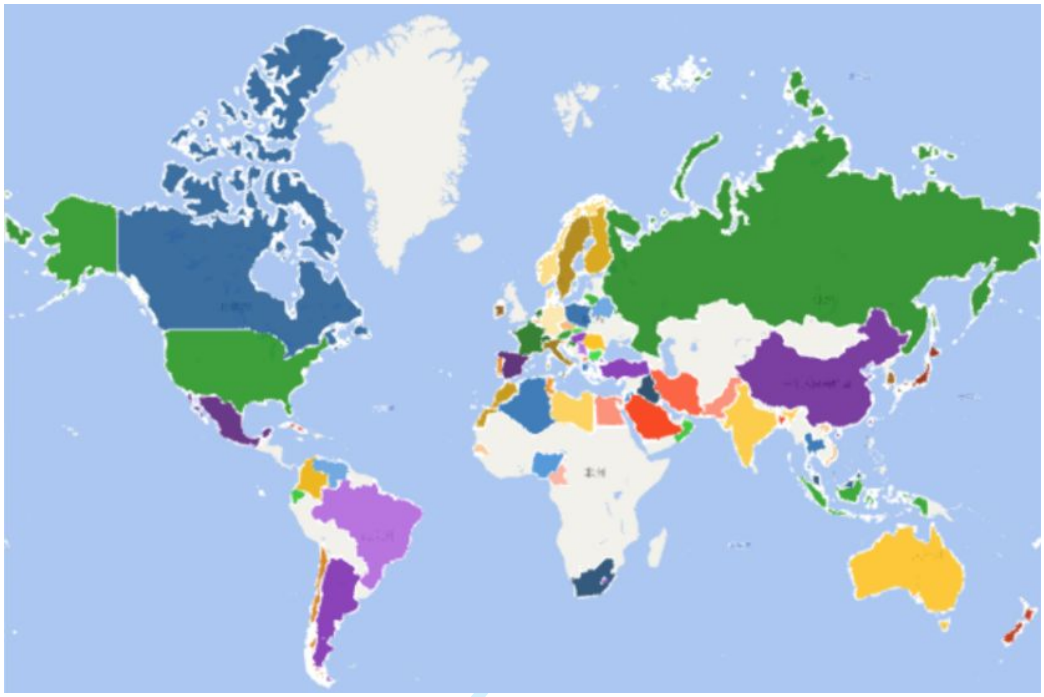

Figure 5. Global geographic distribution of documents from 1970 to 2019.

Figure 6 shows the density of these countries/regions, and the strength of redness of the colour in a country/region, the more documents it has. It shows that China, USA, India and some European countries/regions have more documents published in *IJSS* in the past 50 years. It is reflective of the strength of the *IJSS* relevant disciplines in these countries and the dedicated readership of the journal that had been cultivated there.

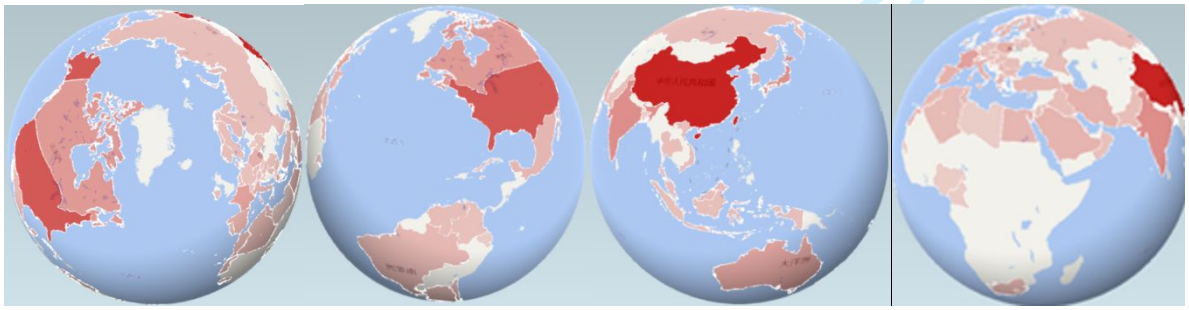

Figure 6. The density of countries/regions published documents in *IJSS*.

Figure 7 presents the cumulative percentage of documents from the top 30 countries/regions. It fits the logarithmic trend line given by $y = 0.2139\ln(x) + 0.209$ with a

goodness of fit of $R^2 = 0.9917$. It also reveals that the top 10 countries/regions have contributed to 73.41% of all the documents. The top 20 countries/regions and top 30 countries/regions have contributed to 86.88% and 92.78%, respectively and is reflective of the diversity of the readership of the *IJSS*.

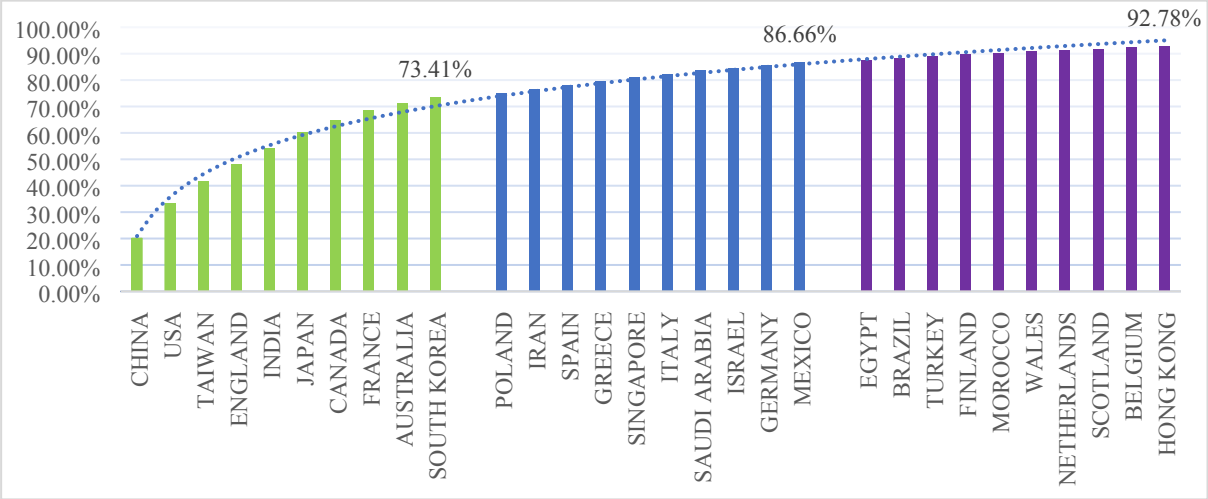

Figure 7. The cumulative percentage of documents from top 30 countries/regions.

3.2 Keywords features

Keywords analysis reveals the features of documents, and indicates the current research hotspots to a large extent since they are the most frequently used or influential words in a document. There are in total 10,459 keywords according to the VoS viewer tool in the documents published in *IJSS* during the past 50 years. Thresholds were selected for the minimum number of occurrences of a keyword in the analysis of the influential keywords such that the total number of keywords down-selected were 60. For each of the 60 keywords, the total strength of the co-occurrence links with other keywords were calculated. The keywords with the greatest total link strength were then selected, and shown in Figure 8.

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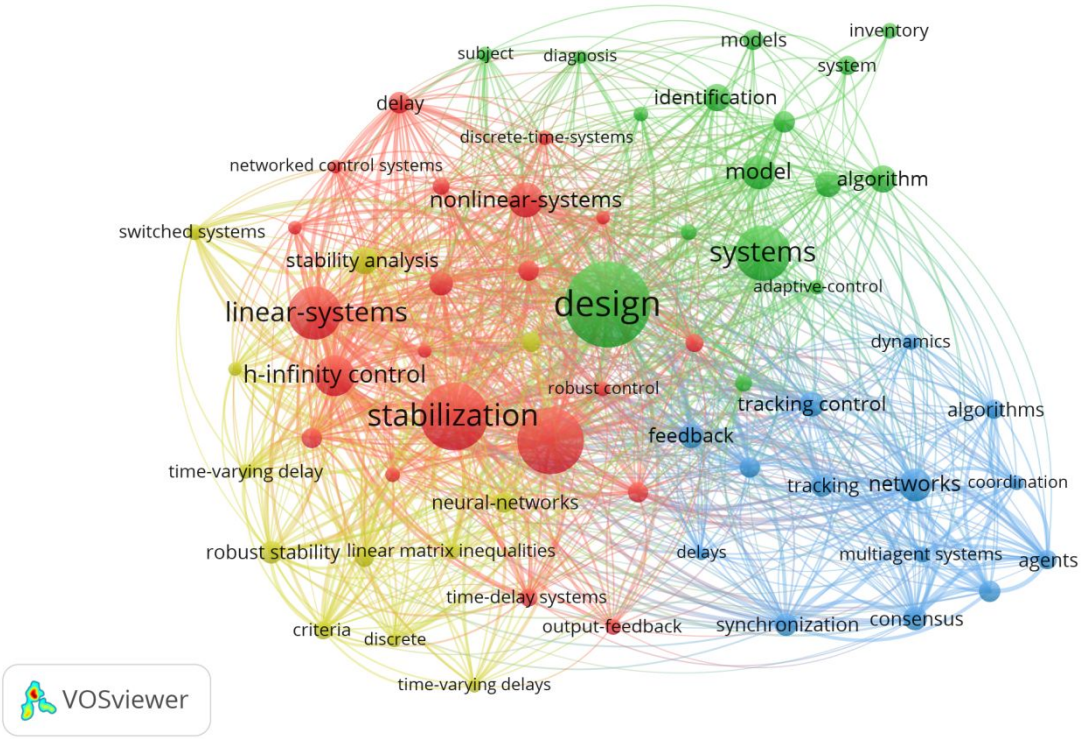
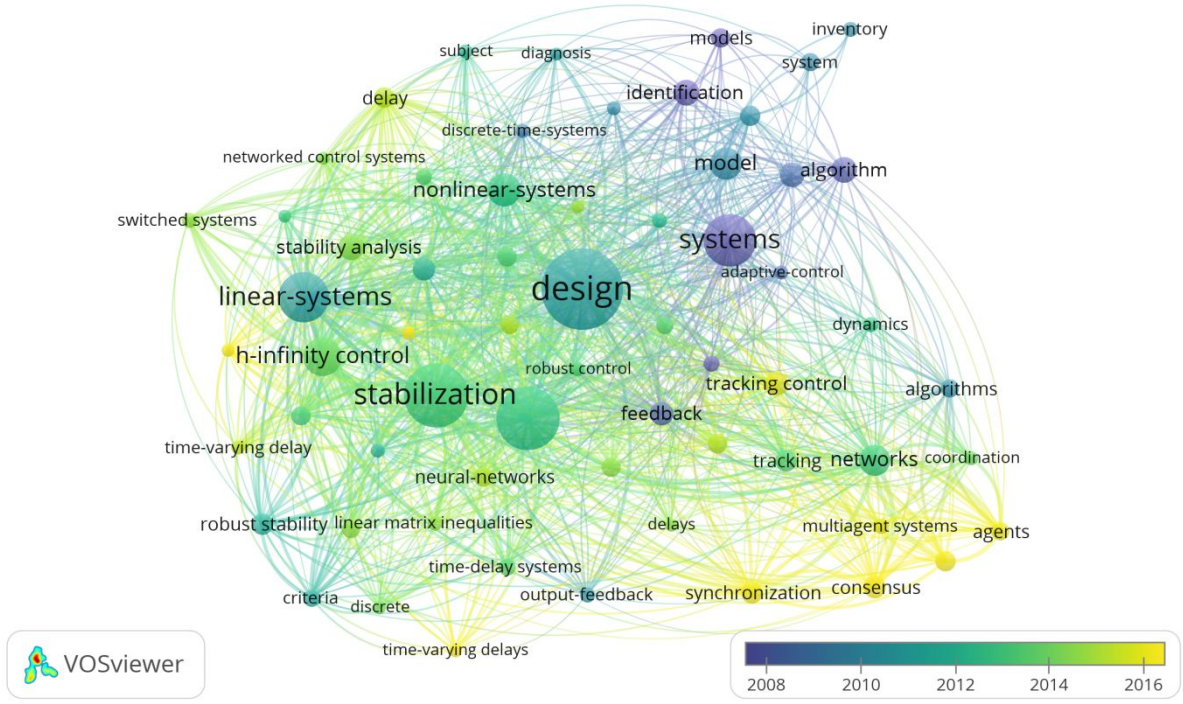


(a) The co-occurrence network.



(b) The time overlay network.

Figure 8. The keyword co-occurrence network of documents in *IJSS*.

In Figure 8 (a), keywords have been divided into four clusters labelled in different colors, i.e., blue, green, red and yellow. In Figure 8 (b), the time overlay network captures the popularity of these keywords covered in the four stages of the 50 years. The first stage was

marked by a focus on systems, models and algorithms. Later, scholars paid attention to feedback, adaptive-control, and discrete-time-systems. During the third stage, popular keywords were transformed to design, linear-systems, h-infinity control, and stabilization. In the recent 20 years, the number of keywords has increased and are focused on newer research directions, such as tracking control, consensus, time-varying delays, synchronization and multi-agent systems.

Further analysis is conducted with the keywords in a way that accounted for the variability of the use of keywords amongst scholars and the different variations that were presented in the keywords for a specific subject. There are mainly two methods to process keywords: (1) Merging of synonyms. For example, stability and stability analysis could be combined into stability analysis. (2) Removal of keywords that are too generic and do not identify a narrow research theme, such as systems and control. These processes were adopted in sorting the keywords by word frequency from high to low, and 30 keywords with word frequency greater than 50 were selected as high-frequency keywords. A 30×30 co-word matrix was then constructed for further analysis towards identifying the hot topics of this journal.

Table 5. High-Frequency keywords (frequency>50)

keywords	frequency	keywords	frequency	keywords	frequency
stability analysis	919	robust control	251	synchronization	184
linear-systems	695	adaptive control	248	discrete-time systems	176
nonlinear-systems	523	tracking control	242	sliding mode control	165
algorithm	410	linear matrix inequality	227	uncertain systems	164
control design	408	consensus	225	identification system	159
h-infinity control	330	time-delay systems	224	output-feedback control	147
dynamics	320	stochastic systems	215	exponential stability	133
neural networks	283	switched systems	215	state estimation	104
optimization	269	multiagent systems	212	markovian jump systems	89
networked control systems	262	robust stability	190	diagnosis	73

The co-word matrix is symmetric. The data on the main diagonal represents the co-occurrence frequency of the keyword with itself. The data on the non-main diagonal elements

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of the matrix represent the co-occurrence frequency between two different keywords. For instance, the common word frequency of stability analysis and linear systems is 343, indicating that these two keywords appear simultaneously in 343 documents. Since most elements in the correlation matrix have values close to zero, this can lead to difficulties in further analysis of this matrix. Therefore, one can be used to subtract the data in the correlation matrix to get the dissimilarity matrix representing the degree of difference between the two words. By using SPSS 26.0, we applied the systematic cluster method on the dissimilarity matrix to get the dendrogram on account of in-group connection and Euclidean distance methods.

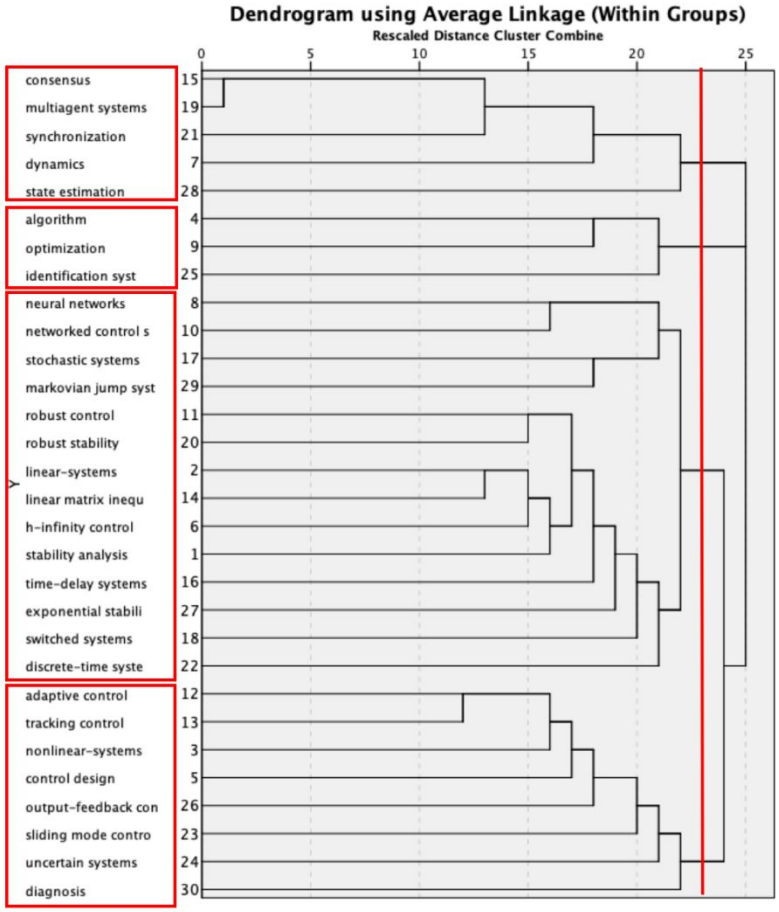

Figure 9. The clusters of the top 30 keywords of documents in *IJSS*.

In Figure 9, all keywords were classified into four categories based on the dendrogram as follows: (1) Consensus, multiagent systems, synchronization, dynamics, and state estimation were included in the first category. The consistency problem is the basic problem of multi-agent system coordination control and has become a trendy subject in the field of systems and control

science in recent years. Meanwhile, synchronization is one of the applications of the consensus problem. As all elements in this category are related to multi-agent systems, and this group is referred to as problems associated with multi-agent systems. (2) The second group is labelled algorithms and optimization with just three keywords of algorithm, optimization, and system identification. (3) Systems and stability as a term generalises the keywords of the third category, in which neural networks, linear systems, other time-related systems, and their stability represent the main context of this group. (4) The rest of the keywords, particularly adaptive control, tracking control, control design, output-feedback control, and sliding mode control, belong to the fourth group referred to as systems control.

On the one hand, keywords have been divided into four clusters according to keywords' frequency and systematic clustering. On the other hand, consideration of the keywords in the title and the abstract information in documents, were placed into 10 following clusters: *Linear system*, *deteriorating item*, *forgetting factor*, *nonlinear system*, *multi-agent system*, *descriptor system*, *predictive control*, *fault detection*, *particle swarm* and *complex network*. In this way, the keywords have been divided into the more specific categories associated with systems, algorithms, parameters and applications. Moreover, because of the dynamic changes of keywords with time, the burst detection analysis of cited keywords was conducted to identify the strongest ones over the different time periods. Table 6 lists the top 12 strongest keywords from 1974 to 2019.

Table 6. The top 12 strongest keywords from 1974 to 2019

Rank	Keywords	Strength	Begin	End	1974-2019
1	system	**45.7279**	1992	2004	
2	identification	**14.8520**	1997	2009	
3	linear matrix inequality	**14.1500**	2006	2013	
4	algorithm	**13.5415**	1993	2006	
5	inventory	**12.5549**	2006	2014	
6	model	**11.2138**	1987	2005	
7	stochastic system	**10.2655**	2008	2011	
8	polynomial	**9.2682**	1991	1996	
9	feedback	**9.1883**	1991	2005	
10	synchronization	**9.1472**	2016	2019	
11	Markovian jump system	**9.0769**	2017	2019	

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12	optimization	**9.0742**	1998	2005

Table 6 shows that the keyword *system* has the maximum burst strength (45.7279), followed by *identification* (14.8520), *linear matrix inequality* (14.1500) and *algorithm* (13.5415). There is a large gap between the first and the rest, confirming that the journal pays more attention to the advanced research related to the theme of systems. This of course is consistent with the title and aim of the journal to devote to the scholarship of systems science. In terms of burst duration, *model* has the longest citation burst duration with 19 years from 1987 to 2005, followed by *feedback* (15 years) and *algorithm* (14 years), indicating that they have remained the core subject areas and themes for the *IJSS*. During the early period of the journal, the keywords of *model*, *polynomial*, and *feedback* were more frequently used, which coincided with the exposition of the initial developments in systems and control studies that were also reflected in the documents in the *IJSS*. There were two keywords, *synchronization*, and *Markovian jump system*, that end in 2019, which reflects that scholars have researched them recently, and is perhaps indicative of their continued attention into the near future.

Figure 10 shows the timeline of keywords by CiteSpace in the *IJSS* documents over the past 50 years. This analysis yields a different set of groups. Here, *linear system* is found to be the largest group of keywords, with a time span ranging from about 1990 to 2017, containing *stability*, *h-infinity control*, *exponential stability*, and *iterative learning control*. The second group about *deteriorating item* was dominant from 1987 to 2013, and included keywords of *time delay*, *sensitivity analysis* and *preventive maintenance*. This end time of 2017 aligns with the launch of the sister journal *IJSS*: Operations and Logistics in 2014 (Fleming & Konstantaras, 2014) which now publishes articles in those themes. The third group *forgetting factor* was active from 1990, and includes the keywords *time varying system*, *sensor network*, and *aggregation operator*. *Nonlinear system* is the fourth group that was dominated by the keyword *robust control*, *fuzzy system*, and *neural control*. The next group is *multi-agent system* that is composed of keywords like *adaptive control*, *tracking control*, and *leader following consensus*. *Descriptor system* is the sixth group, which has an emphasis on *state feedback*, *discrete event system*, and *synchronization*. *Predictive control* is the next group, that includes *output feedback*, *finite-time stability*, *state estimation*, and *disturbance observer*. It is followed by the group, *fault*

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detection, containing keywords like *fault diagnosis*, *sliding mode observer*, and *fault estimation*. *Particle swarm* is the second-to-last group that that is devoted to *diagnosis*, and *particle swarm optimization*. Finally, *Complex network* is the last group, consisting of the keywords like *genetic algorithm*, *dynamical network* and *linear matrix inequalities*. Over time, the research topic and popular keywords of documents that received much attention in the *IJSS* have changed continually to reflect the changing landscape of research in systems and control. The recent focus of the articles in the journal has been on observer design, dynamic surface control, backstepping control and its advances.

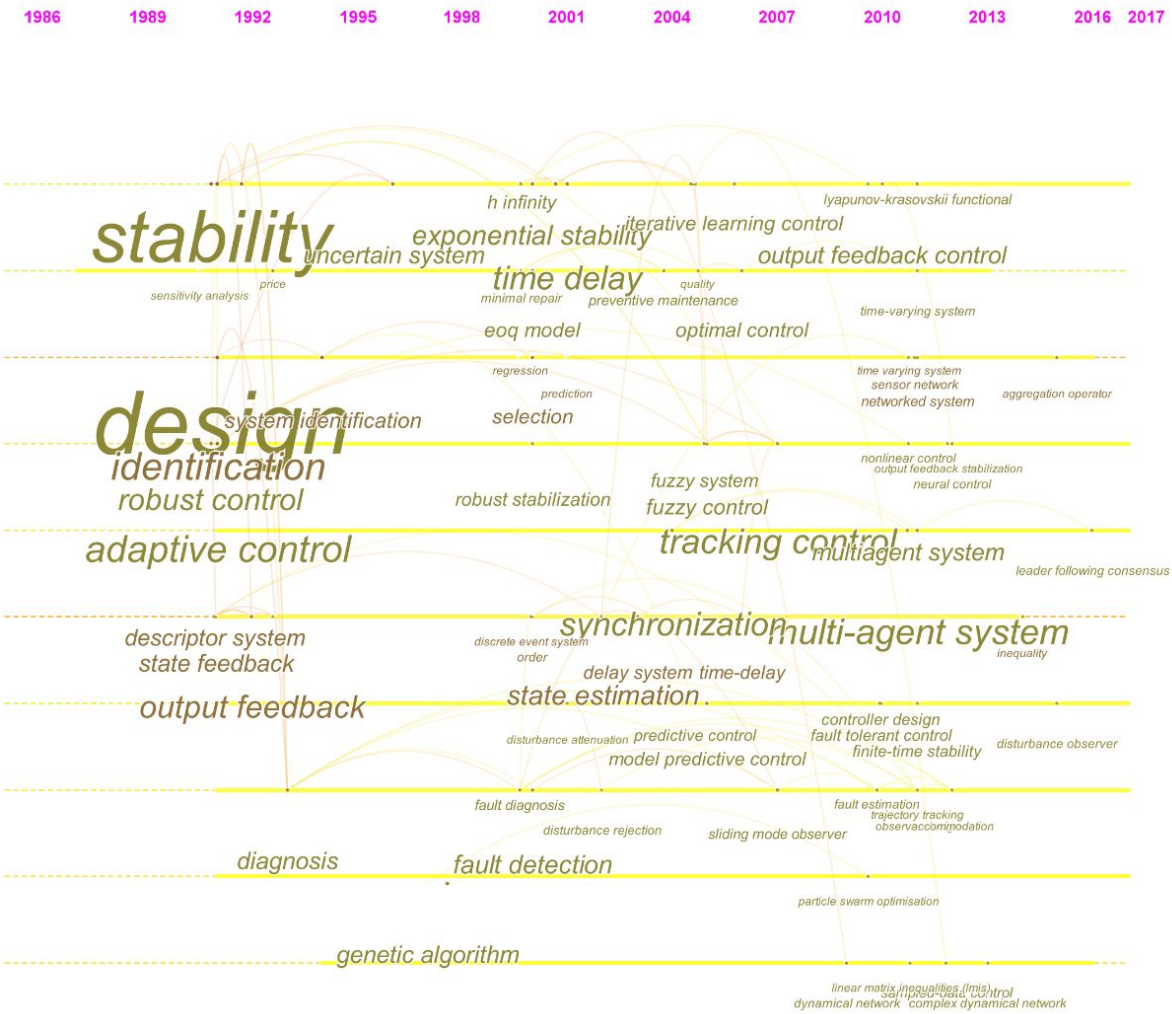

Figure 10. The timeline view of burst keywords in *IJSS*. Each row represents a category, and there is linear system, deteriorating item, forgetting factor, nonlinear system, multi-agent system, descriptor system, predictive control, fault detection, using pareto archive particle swarm and complex network in order.

3.3 Prediction of research trends

After analyzing the keywords in the *IJSS* documents published in the past 50 years, an attempt was made to predict the future research directions in the next three years through analyzing 30 keywords that were cited more than 50 times during 1970 to 2019. Tables 7 and 8 list the Box-Pierce tests of *ARIMA* models under the prerequisite of lag=5 and lag=10.

Table 7. Box-Pierce test (Lag=5)

keywords	p-value	keywords	p-value	keywords	p-value
stability analysis	0.78	robust stability	0.9439	output-feedback control	0.7233
stochastic system	0.8842	discrete-time systems	0.8741	diagnosis	0.7394
linear-systems	0.7301	exponential stability	0.5782	algorithm	0.3167
h-infinity control	0.4938	markovian jump systems	0.5842	optimization	0.7901
neural networks	0.8337	nonlinear systems	0.9442	identification systems	0.6549
networked control systems	0.7425	control design	0.8824	state estimation	0.767
robust control	0.9299	adaptive control	0.6528	dynamics	0.6702
linear martix inequality	0.9003	tracking control	0.9883	consensus	0.9695
time-delay systems	0.9686	sliding mode control	0.6863	multiagent systems	0.9097
switchd systems	0.8917	uncertain systems	0.9124	synchronization	0.5155

Table 8. Box-Pierce test (Lag=10)

keywords	p-value	keywords	p-value	keywords	p-value
stability analysis	0.9881	robust stability	0.9881	output-feedback control	0.9285
stochastic system	0.996	discrete-time systems	0.9469	diagnosis	0.9133
linear-systems	0.9339	exponential stability	0.6126	algorithm	0.5005
h-infinity control	0.7806	markovian jump systems	0.9419	optimization	0.9584
neural networks	0.937	nonlinear systems	0.9675	identification systems	0.8708
networked control systems	0.841	control design	0.9914	state estimation	0.9427
robust control	0.9254	adaptive control	0.9024	dynamics	0.9302
linear martix inequality	0.9462	tracking control	0.9997	consensus	0.9993
time-delay systems	0.9757	sliding mode control	0.9681	multiagent systems	0.997
switchd systems	0.963	uncertain systems	0.9472	synchronization	0.8644

The results in the above tables show that all p-values are more than 0.05, namely, all constructed models are suitable for making predictions and time-series analysis applied in this

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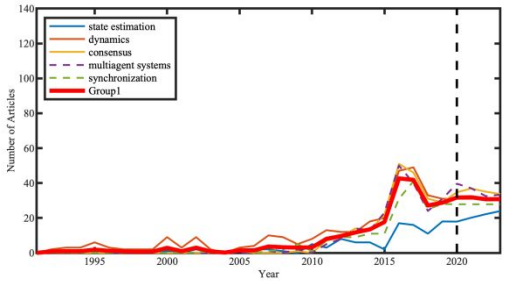
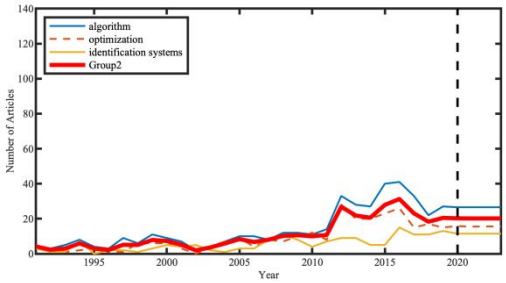
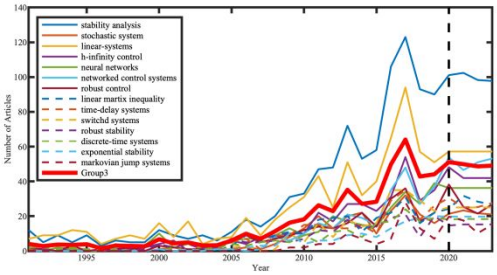
scenario. The ARIMA model simulations show the evolution and prediction of each keyword as depicted in Figure 11 showing the future trends of keywords and their groups that were obtained from the systematic clustering.



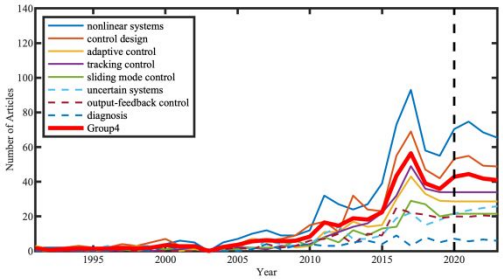
(a) Tendency with Group 1.



(b) Tendency with Group 2.



(c) Tendency with Group 3.



(d) Tendency with Group 4.

Figure 11. The trends of groups by ARIMA model.

From Figure 11, three characteristics of keywords can be concluded:

(1) All the selected keywords were mentioned more frequently after 2006, indicating that the current trending research topics began to receive close attention and developed rapidly from 2006. In particular, *linear systems* and *linear matrix inequality* increased more than twice as much as the previous year, revealing that scientists began to pay renewed attention to linear systems' related problems after 2006. After a period of fluctuation, the occurrence frequency of most keywords increased significantly after 2015. Amongst them, *stochastic systems*, *switched systems*, *networked control systems*, *uncertainty systems*, *adaptive control output-feedback*, and other keywords increased by more than twice, from points to the close linkage of complex systems and control concepts from 2015. Along with two years of rapid growth, the frequency of some keywords began to decrease from 2018. The attention given to keywords of *robust control*, *robust stability*, *linear matrix inequality*, and *linear systems* began to fall, reflecting that studies on the linear system and system robustness had achieved maturity.

(2) In Group 1, keywords about controllability have been in a stable state in recent years

after their rapid developments, and have no obvious future growth trend. Moreover, some currently hot topics like multi-agent systems are likely to see reduced interest from scientists in the next three years as the main challenges are successfully addressed. Algorithm and optimization in Group 2 will not experience much change in the future reflecting their need in a generic sense to a wide class of problems. In Group 3, keywords including systems and their stability generally display a rising trend though their number fluctuates. In the next three years, all keywords in this group will attract more attention from scholars, but their growth rate will slow down as seen in the typical historical trends. In Group 4, keywords about systems control will have consistent development, with a rising trend in the next three years as new emerging systems demand control systems developments.

(3) Overall, the documents in the journal show increasingly diversified characteristics since 2005, as reflected in the growth in keywords. As *stability analysis* in Group 3 showed, there are 123 more documents related to it in 2017 than before, and other keywords with similar patterns. After 2020, the numbers of documents with respect to various keywords in all Groups are characterized by trends that are expected to be steady without much fluctuations. If this trend prediction is realised, the high-frequency keywords identified above will continue to receive attention while newer in the future as newer topics of systems science emerge.

4. Discussions

The presented results reveal the characteristics of documents in the *IJSS* as viewed through the bibliometrics analysis of the past 50 years. To give further details on trends in the topics of research, we analyzed the contents of documents cited more than 15 times in the last 20 years towards making some observations on the problems addressed, popular methodologies and the impact in the relevant fields.

4.1 Problems addressed

Due to the aim and scope of the *IJSS*, the documents in the journal have explored a variety of problems in different fields, primarily in those of computer science, automation control systems, operations research management sciences, mathematics, and robotics. The addressed problems are categorized into the following themes:

(1) Control. It is one of the key techniques used in various systems, and documents in the

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recent 20 years mainly refer to H-infinity control, tracking control, robust control, sliding mode control and output-feedback control. For example, finite-time H-infinity control has been studied for stochastic time-delayed Markovian switching systems (Qi & Gao, 2016), a class of discrete-time Markovian jump systems with partly unknown time-varying transition probabilities (Cheng et al., 2015), and periodic piecewise linear systems (Xie et al., 2017). As for tracking control, (Lin et al., 2017) proposed a novel optimal tracking control scheme for a class of discrete-time nonlinear systems using generalized policy iteration adaptive dynamic programming algorithm, and obtained better performance than other methods. Repetitive control scheme was established for state tracking control of uncertain stochastic time-varying delay systems by equivalent-input-disturbance approach (Sakthivel et al., 2017). Considering robust control, operator-based robust control was proposed for nonlinear systems with Prandtl-Ishlinskii hysteresis (Deng et al., 2011). (Wang et al., 2018) studied robust iterative learning control for multi-phase batch processes using an average dwell-time method with 2D convergence indices. A class of nonlinear discrete-time networked systems (Ma et al., 2011) was researched with respect to sliding model control, and (Ma et al., 2011) designed for uncertain delay systems with partial actuator degradation. As a common research topic, output-feedback control was studied for a flexible air-breathing hypersonic vehicle using T-S fuzzy approach (Hu et al., 2014) and for a class of discrete-time fuzzy dynamic systems (Lam & Zhou, 2007). Besides, there are some intersection of control disciplines, such as adaptive neural control of non-affine pure-feedback non-linear systems with input nonlinearity and perturbed uncertainties (Zhang et al., 2012), H-infinity state tracking model reference adaptive control problem (Wu & Zhao, 2015), and adaptive robust control of nonlinear systems in semi-strict feedback form (Yang et al., 2007). Documents on the control category in the journal were selected in recent two decades based on higher relative citation, listed in Table 9.

(2) System. Switched systems, multiagent systems and stochastic systems are the most researched in these years. Specifically, H-infinity adaptive tracking control (Wu & Zhao, 2015) and fault recoverability analysis (Yang et al., 2012) were applied to switched systems using average dwell-time method, and the least eigenvalue method, respectively. Multiagent systems had a focus on consensus, including multi-target consensus circle pursuit (Pei et al., 2016), distributed robust finite-time nonlinear consensus protocols (Zuo & Tie, 2016), and group consensus with directed information exchange (Yu & Wang, 2012). In terms of stochastic systems, (Yin et al., 2013) studied data-driven monitoring and its application to batch processes.

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Optimal least-squares linear estimation problem was researched for a class of discrete-time stochastic systems with random parameter matrices and correlated additive noises (Linares-Perez et al., 2014). Table 10 lists more information on the system theme.

(3) Stability analysis. It plays a significant role and importance to systems performance. For any given control system, stability is of primary concern for system operation. In general, stability analysis contains finite-time stability and stabilization (Xiang & Xiao, 2013), existence and global stability of equilibrium point (Nie & Cao, 2012), delay-dependent stability analysis (Wu et al., 2012). (Duan et al., 2015) improved robust stability criteria for a class of Lur'e systems with interval time-varying delays and sector-bounded nonlinearity. Stability analysis of hybrid switched nonlinear singular time-delay systems was studied with stable and unstable subsystems by free-weighting matrix approach (Zamani et al., 2014). The Lyapunov-Razumikhin approach was used for stability analysis of logistics networks with time-delays (Dashkovskiy et al. 2010). Table 11 lists the information of stability theme analysis.

(4) Decision-making. Research in the recent two decades studied many decision problems in relation to consistency, consensus, and evaluation, which have been applied to project management, supply chains, behaviour recognition of ground vehicle and portfolio selection. (Yazdian et al, 2016) proposed joint optimization of remanufacturing, pricing and warranty decision-making for end-of-life products. The optimal retailer's ordering policies were established with trade credit financing and limited storage capacity (Yen et al, 2012). Joint pricing and replenishment decisions (Tsao & Sheen, 2007), and non-instantaneous deteriorating items under delay in payments (Tsao, 2016) were discussed in portfolio selection. Evaluations about auto spare parts industry (Wu & Tsai, 2012) and sustainable energy crop (Peng & Wang, 2017) were analysed systemically. (Taleizadeh & Noori-daryan, 2016) proposed a decentralized three-layer supply chain and (Liang, 2007) established new method for production/transportation planning decisions in a supply chain. Table 12 lists relevant documents in decision making.

(5) Optimization. This is a popular research direction in the journal, and contains multi-objective optimization, system optimization, multi-modal optimization and parameter optimization. (Taleizadeh et al., 2010) optimized multi-product multi-chance-constraint inventory control system with stochastic period lengths and total discount under fuzzy purchasing price and holding costs. Optimum synthesis of a four-bar mechanism was established using the modified bacterial foraging algorithm (Mezura-Montes et al.,2014). (Zhan

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et al., 2014) proposed a multi-objective optimization model to deal with a multi-supplier, multi-affected area, multi-relief, and multi-vehicle relief allocation problem in disaster relief logistics. Table 13 lists example documents on the optimization theme.

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Table 9. Documents about control in *IJSS*

Control	Author	Year	Problem addressed	Methodology
H-infinity control	Chen & Lam	2004	Uncertain state-delayed systems	Algebraic Riccati inequalities
	Wu et al.	2009	Continuous-time switched stochastic hybrid systems	Average dwell-time approach and Lyapunov function technique
	Liu et al.	2012	Nonlinear systems with time-delay	T-S fuzzy model approach
	Ghous & Xiang	2016	2-D continuous switched delayed systems	Multiple Lyapunov functional approach
Tracking control	Zhao & Jia	2016	Multi-agent systems under actuator faults	Lyapunov approach and graph theory
	Sakthivel et al.	2017	Uncertain stochastic time-varying delay systems	Equivalent-input-disturbance approach
	Liu et al.	2017	A class of discrete-time nonlinear systems	Generalized policy iteration adaptive dynamic programming algorithm
Robust control	Huang & Kuo	2002	A two-degree-of-freedom manipulator	Nonlinear time-varying systems
	Deng et al.	2011	Operator-based robust control	Prandtl-Ishlinskii hysteresis
	Wang et al.	2018	Robust iterative learning control	An average dwell-time method
Sliding mode control	Djemai et al.	2011	High-order sliding mode control of a DC motor drive	A switched controlled multi-cellular converter
	Ma et al.	2011	A class of nonlinear discrete-time networked systems	Novel discrete switching function and linear matrix inequality
	Zhao & Zou	2012	Terminal principle and system synchronisation theory	Finite-time synchronised approach
Output-feedback control	Dong	2012	A group of nonholonomic mobile agents	Lyapunov techniques and graph theory
	Karimi	2013	Markovian jump systems	Lyapunov stability theory
	Hu et al.	2014	A flexible air-breathing hypersonic vehicle	T-S fuzzy approach

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Table 10. Documents about systems in *IJSS*

Control	Author	Year	Problem addressed	Methodology
Switched systems	Davila	2011	Continuous and discrete state reconstruction	High-order sliding-mode observers
	Du et al.	2012	Sensor fault estimation and compensation	Novel time-delay switched descriptor state observer
	Yang et al.	2012	Fault recoverability analysis	The smallest eigenvalue of method
Multiagent systems	Luo et al.	2011	The topology reorganisation of formations	A decentralised algorithm
	Sakurama & Nakano	2015	Average-consensus with heterogeneous time delays	Delay-transition and the delay-weighted Laplacians
	Pei	2016	Multi-target consensus circle pursuit	A distributed multi-flocking method
Stochastic systems	Cong & Zou	2010	A new delay-dependent exponential stability criterion	Lyapunov-Krasovskii method and Markov process
	Yao et al.	2011	H-infinity filtering	Linear matrix inequality
	Shen et al.	2014	Dissipative control	T-S fuzzy model

Table 11. Documents about stability analysis in *IJSS*

Author	Year	Problem addressed	Methodology
Wang et al.	2001	Stabilization of synchronous generators	Hamiltonian function approach
Yang et al.	2006	Practical stability of closed-loop descriptor systems	Lyapunov functions
Liu & Liu	2008	Uniform stability of discrete impulsive systems	A discrete impulsive synchronization scheme
Ji et al.	2011	Discrete linear time-delay systems	Lyapunov functional and matrix inequalities
Dashkovskiy et al.	2012	Logistics networks with time-delays	A Lyapunov-Razumikhin approach
Huang	2013	Fuzzy descriptor systems	T-S fuzzy model and linear matrix inequalities
Liu et al.	2016	A class of nonlinear systems with time-varying delay	Inequality and a fuzzy Lyapunov-Krasovskii functional
Din	2017	Neimark-Sacker bifurcation of a host-parasitoid model	Maximum Lyapunov exponents and Neimark-Sacker bifurcation
Zhou $ Qian	2017	Periodically time-varying systems	Pointwise frequency responses framework

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Table 12. Documents about decision making in *IJSS*

Author	Year	Problem addressed	Methodology
Liang	2006	Project management decisions	Interactive fuzzy linear prograннuing approach
Liang	2007	Production/transportation planning decisions	Fuzzy goal programming
Yang et al.	2011	Intermittent communication	Optimal consensus-based distributed estimation
Wu & Tsai	2012	Evaluate the criteria in auto spare parts industry	AHP and DEMATEL methods
Wangn & Xin	2013	Obstacle avoidance	Optimal consensus algorithm
Ho et al.	2013	Synthesizing the elements of comparison matrix	Analytic Hierarchy Process
Oh et al.	2014	Behaviour recognition of ground vehicle	String pattern matching theory
Taleizadeh & Noori-daryan	2016	Coordinating policy in a supply chain	Stackelberg-Nash equilibrium
Peng & Wang	2017	Select sustainable energy crop	Cloud decision model

Table 13. Documents about optimization in *IJSS*

Author	Year	Problem addressed	Methodology
Tang et al.	2003	Average-cost optimization problems	Policy iteration and value iteration algorithms with Poisson equation
Molina-Cristobal et al.	2006	Evolutionary optimization in multiobjective control	Evolutionary Algorithms and Linear Matrix Inequalities
Xu & Hu	2008	Availability optimization of repairable system	Strong continuous semi-group theory
Singh & Parhi	2011	Path optimization of a mobile robot	Artificial neural network controller
Ding et al.	2011	Target coverage optimization of wireless sensor networks	A multi-objective immune co-evolutionary algorithm
Iacca et al	2012	Optimization in noisy environments	A compact algorithm
Brest et al.	2013	Dynamic optimization	Differential evolution and ant-stigmergy
Mezura-Montes et al.	2014	Optimum synthesis of a four-bar mechanism	Modified bacterial foraging algorithm
Giagkiozis et al.	2015	Multi-objective optimization	Population-based algorithms

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4.2 Popular Methodologies

With more and more complex and sophisticated modern systems demanding performance, reliability and increasing autonomy, highly analytic and numeric-based methods are not sufficient to deal with manufactured and natural systems, such as biological, ecological and socio-economic systems. The reason is that these systems require multiple interacting and interconnected, and a common information-processing framework. Therefore, a wide range of new theories, methodologies and techniques are required to address the requirements, and engineering and integration may be an effective way to deal with these demands. Through reviewing techniques during the past 20 years, we can divide them into three types as follows:

(1) Fuzzy theory. This is a useful tool to handle uncertain and complex information in systems with various expression forms, such as intuitionistic fuzzy sets (Peng et al., 2015), type-2 fuzzy sets (Zhao & Xiao, 2015), hesitant fuzzy sets (Peng et al., 2015) and hesitant fuzzy linguistic term sets (Zhou et al., 2016). Several novel operators, containing cubic fuzzy Einstein aggregation operators (Fahmi et al., 2018), intuitionistic fuzzy evidential power aggregation operator (Jiang & Wei, 2018), intuitionistic uncertain linguistic partitioned Bonferroni means (Liu & Liu, 2017), were proposed to calculate conveniently and rationally. In addition, advanced fuzzy theory has been applied to evidence reasoning (Zhou et al., 2016), goal programming (Liang, 2007), consistency and consensus reaching model (Zhang et al., 2016), and decision support systems (Zhang et al., 2016). Another contribution is in system control. Takagi-Sugeno fuzzy model (Sheng & Ma, 2014) is one of the most used techniques in stability analysis and controller design, as well as fuzzy Lyapunov-Krasovskii function (Liu et al., 2016) and Stackelberg-Nash equilibrium (Taleizadeh & Noori-daryan, 2016).

(2) Lyapunov theory. Lyapunov indirect method and Lyapunov direct method are two main approaches to analyze the stability of linear and nonlinear systems, and they are regarded as general and useful tool in stability analysis and control design. In the recent 20 years, Lyapunov theory and its variants, such as fuzzy Lyapunov-Krasovskii function, have been used for finite-time stability and stabilization (Liu et al., 2016), 2-D nonlinear discrete systems (Ye & Wang, 2011), discrete linear time-delay systems (Ji et al., 2011), and switched neutral systems (Li, et al., 2013). Moreover, Lyapunov-Krasovskii function has also been applied to

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the synchronization of discrete-time complex networks (Banu & Balasubramaniam, 2014), and cost control of synchronization in uncertain complex delayed networks (Li et al., 2012).

(3) Machine learning. This is a branch of artificial intelligence in which a computer generates rules and relationships based on raw data that has been fed into it. Neural network as the classical machine learning algorithm, has been used in most of documents in the journal. (Zhao & Jia, 2016) proposed neural network-based adaptive consensus tracking control for multi-agent systems under actuator faults. Anti-periodic solutions were obtained for a class of Cohen-Grossberg neural networks with time-varying delays on time scales (Li et al., 2011). (Tian-Shyug et al., 2002) forecasted an opening cash price index and (Memon & Khan, 2001) studied camera calibration and three-dimensional world reconstruction of stereo-vision using neural networks.

4.3 Impact in the relevant fields

As the journal evolved over the 50 years, *IJSS* has made impact in the relevant fields of Computer Science, Theory & Methods, Automation & Control Systems, and Operation Research & Management Science. Impact Factor (IF) is one of the influential factors to capture this characteristic. Figure 12 describes the IF of the *IJSS* from 2000 to 2019. The result shows that it has increased in general during these years, from 0.2019 to 2.149 till now. After 2010, its IF started to increase, and improved by nearly two times, though in the past four years it has fluctuated in a narrower range. These statistics indicate that the journal has developed steadily in the multiple domains, and possess potential to further enhance its influence. Moreover, in the past twenty years, it has mainly focused on Operation Research & Management Science, Automation & Control Systems, as well as Computer Science, Theory & Methods. The percentile rank of these categories has also improved, implying that papers related to research in these fields have received attention and better recognized by more scholars in the last decade. Similar to the trend in each category, until 2010, their percentile rank increased rapidly. The Computer Science, Theory & Methods, in particular, changed from the least valued research filed with a very low percentile to one with higher percentile and more academic impact when compared with others disciplines.

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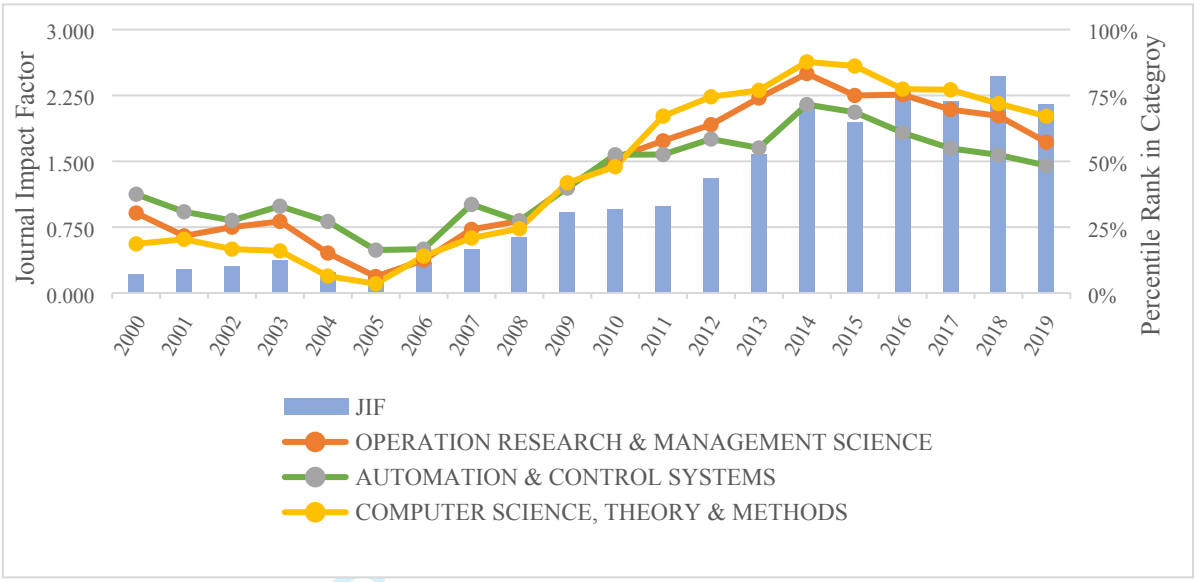

Figure 12. Impact Factor of *IJSS* from 2000 to 2019.

According to the analysis and discussions in Subsection 4.1 and 4.2, possible future directions likely to receive attention are concluded as follows: (1) With the development of advanced information technology and in the big data era, machine learning, especially for deep learning (Wu et al., 2017; Liu et al., 2020), has been popularly used both in theory and application because of better performance and higher effectiveness. Therefore, selecting a suitable deep learning method for a specific application may be an effective way to handle complex systems challenges. (2) Under more uncertain environments, novel fuzzy expressions have been proposed to handle imprecise issues from the point of human recognition, such as probabilistic linguistics term sets (Pang et al., 2016) and nested probabilistic linguistic term sets (Wang et al., 2019). According to the characteristics of systems, scholars would need to choose an appropriate fuzzy tool to obtain effective performance. (3) As society develops, the future research needs to give attention to the wider system level requirements, which embody the trend of trans-disciplinarily, integration of disciplines and scalability. The increasing demands for a systems approach to dealing with complexity challenges ranging from technical disciplines of engineering to social disciplines such as public health, is likely to need development of new systems science methodologies. Need for increased autonomy of operation in sectors like transport, energy and manufacturing where the abundance of data requiring machine intelligence are also key drivers for research developments in autonomous and intelligent systems.

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5. Conclusions

In this paper, we have made a comprehensive review of the *International Journal of Systems Science (IJSS)* to celebrate the 50th anniversary from 1970 to 2019. By evaluating bibliometric indicators, fundamental characteristics of documents in the journal have been presented including types, the number of documents, citations and H-index over the years. With the help of bibliometric analysis, the features of keywords have been revealed through analyses involving clustering, burst keywords and development trends, and illustrated by VoS viewer and CiteSpace. In terms of frequency of keywords, four groups have been obtained by the hierarchical clustering method, while eight classes have been clustered when combined with document title and abstract information. The burst keywords analysis has been conducted by burst detection analysis, and the trends have been described by the timeline analysis. In order to predict the trends of keywords and their groups, Autoregressive Integrated Moving Average (ARIMA) models have been used to forecast their evolution for the next three years. Further discussions have been provided on three aspects, namely, problems addressed, popular methodologies, and impact in the relevant fields. The main findings are summarised as follows:

(1) *IJSS* is an international journal, with a long history of influence in the fields of Automation & Control Systems, Computer Science, and Operations Research & Management Science. In addition, the number of citations has shown an upward trend in the main during the past 50 years, indicating that scholars have increased following of this journal.

(2) Thus far, documents in the *IJSS* have come from 88 countries/regions around the world, especially from Europe, Asia, Australia and America. Moreover, the most prolific country/region is China, followed by the USA, Taiwan, United Kingdom and India, which is indicative of the strength of the relevant disciplines in the respective countries.

(3) Keywords have been divided into four groups in terms of frequency and co-word matrix by a systematic cluster method. These are *multi-agent systems*, *algorithm and optimization*, *systems and their stability*, and *system controllability*. The ARIMA model analysis shows that the trends of Group 1 and Group 2 are in a stable state, while Group 3 has shown a growing trend but the growth rate is predicted to slow down in the next three years, and Group 4 has a clear rising trend.

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(4) Documents in the past 20 years, viewed in terms of problems addressed, popular methodologies, and impact in the relevant fields, were further summarised and analysed.

The analysis in this paper have served to give an insight into the evolution of the profile of the *IJSS*. Identification of the timeline of keywords, and prediction of future research directions likely to receive coverage in the journal were also made. It would certainly be of interest in the future, to investigate through bibliometric analysis dynamically, the evolution of core systems concepts of complexity, autonomy and intelligence and also study of emerging technologies, such as adaptive and learning systems, networked systems and cyber-physical systems in the context of systems science.

Acknowledgments

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