Demystifying Artificial Intelligence based Behavior Prediction of Traffic Actors for Autonomous Vehicle- A Bibliometric Analysis of Trends and Techniques

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ABSTRACT

Background: The purpose of this study is to examine, using bibliometric methods, the work done on behavior prediction of traffic actors for autonomous vehicles using various artificial intelligence algorithms from 2011 to 2020.

Methods: Using one of the most common databases, Scopus, numerous papers on behavior prediction of traffic actors for autonomous vehicles were retrieved. The research papers are being considered for the period from 2011 to 2020. The Scopus analyzer is used to obtain some results of the study, such as documents by year, source, and country and so on. VOSviewer Version 1.6.16 is used for the analysis of different units such as co-authorship, co-occurrences, citation analysis etc.

Results: In our study, a database search outputs a total of 275 articles on behavior prediction for autonomous vehicle from 2011 to 2020. Statistical analysis and network analysis shows the maximum articles are published in the years 2019 and 2020 with United State contributed the largest number of documents. Network analysis of different parameters shows a good

potential of the topic in terms of research.

Conclusions: Scopus keyword search outcome has 272 articles with English language having the largest number. Authors, documents, country, affiliation etc are statically analyzed and indicates the potential of the topic. Network analysis of different parameters indicates that, there is a lot of scope to contribute in the further research in terms of advanced algorithms of computer vision, deep learning, machine learning and explainable artificial intelligence.

Keywords: vehicle behavior prediction, pedestrian behavior prediction, autonomous vehicle, intelligent vehicle, ADAS, machine learning, deep learning, citation, co-occurrence.

I.   INTRODUCTION

Autonomous vehicle is an open research problem due to many issues such as safe navigation, trajectory prediction and behavior understanding of surrounding road agents [1], [2]. Trajectory or motion prediction for autonomous driving is problem of predicting long-term or short term spatial information of various traffic actors such as pedestrians, bus, car and animal, etc. These traffic actors' behaviors are dynamic and stochastic in nature so accurately prediction of trajectory is very crucial for safe navigation of autonomous vehicle [3], [14].

The early detection of the intention of drivers in nearby vehicles at an intersection with complex traffic flow will allow advanced driver assistance systems (ADAS) to alert the driver in advance or prompt their subsystems to assess the danger and intervene early. Although numerous drivers have different driving characteristics, the human-driven vehicle kinematic parameters can be used as a predictor for predicting the driver's intention within a short time [4], [5].

For autonomous driving systems, the precise trajectory prediction of nearby road users is important. Road users with various types of attitudes and styles add uncertainty to the environment in mixed traffic flows, which involves understanding interactions between road users while predicting their possible trajectories.
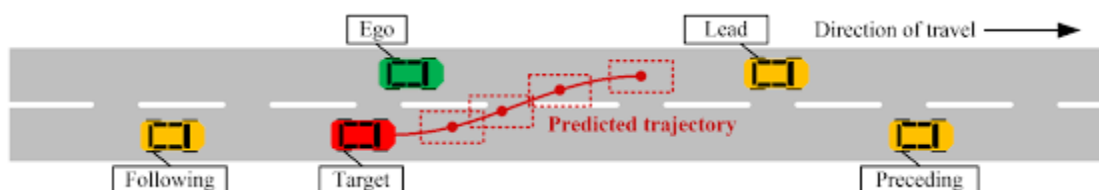

Figure 1: Vehicle trajectory prediction

Different factors such as the randomness of driver/cyclist/pedestrian activities, heavy

interactions with other road users, and spatial constraints of road geometry also make it difficult to predict the movement of road users around the autonomous vehicle. [6], [7].
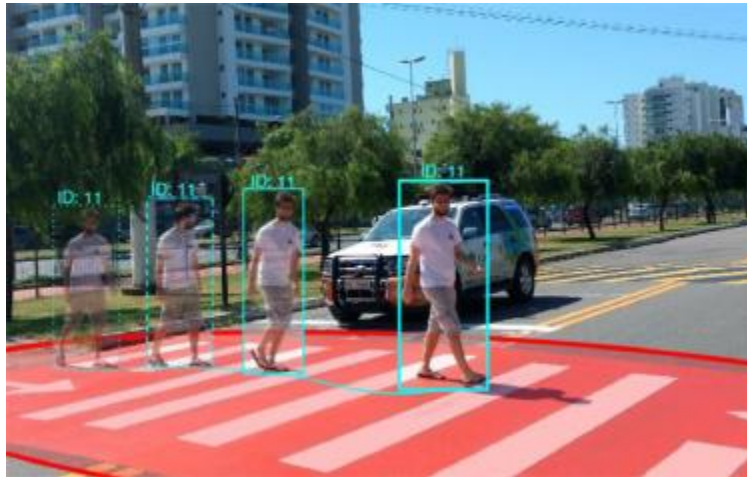

Figure 2: Pedestrian behavior prediction

One of the key problems facing autonomous ground vehicles is to consider the actions and intentions of humans. More precisely, it is much more difficult to infer the motives and actions of vulnerable road users like pedestrians when it comes to dynamic situations such as urban traffic scenes. [8], [15], [16].

It is necessary to recognize, infer, and predict the purpose and future actions of pedestrians in applications, such as autonomous driving. This ability enables vehicles to prevent accidents and enhance the protection and efficiency of driving. In enabling more efficient human-robot/vehicle interaction and collision avoidance, precise pedestrian pose and location prediction has a huge impact [22], [23].

The researchers have used a very powerful and wide variety of algorithms for trajectory prediction of surrounding autonomous vehicle traffic actors. Spatial-temporal graph generation adversarial network architecture (STG-GAN), dynamic Bayesian network (DBN), bidirectional long-term memory (Bi-LSTM), recurrent neural network (RNN) with long short-term recurrent network (RNN) is the most common algorithms. [9], [10], [11].

II. BIBLIOMETRIC ANALYSIS

The term "Bibliometrics" can be split up as 'Biblio' which means books and 'metrics' implies measurement. Based on papers, journals, citations, geographical locations, and other criteria, the bibliometric technique is commonly used to interpret research data quantitatively. This kind of research also allows the authors to recognize the gaps in the literature [24].

The objectives of this bibliometric survey are as follows:

- To analyze the pattern of research in the behavior prediction for autonomous vehicle field.
- To differentiate between the creations of behavior prediction based on the geographical locations of the world
- Identify publication trends through university and research institution affiliations and their authors.
- To study the citation, the citation count of the publications
- To evaluate the language type used in the publications.

It is important to have in-depth knowledge of advancing research in that field and the number of authors contributing to such research when researching a particular area. Significant amounts of knowledge are accessible as technology advances; numerous methods are used to identify different trends, such as bibliometrics, webometrics, scientometrics, and H-index. A bibliometric research was carried out to review using data obtained from Scopus to identify a set of bibliometric enactment indicators such as quantitative efficiency indicators and qualitative indicators like citations and the Hirsch index to achieve these goals (h -index).

2.1 Primary Database Collection

There are many popular databases worldwide, such as scopus, web of science, google scholar, scimago etc. These databases are having a very wide range of publications. Out of these scopus- the most popular and one of the largest database, is used for the analysis. The keywords are used for search have given a total of 275 number of publication results. The different keywords are used for the searching of the databases across the world. There is no any restriction on country, language etc. Each publication has the information such as author, country, citations, documents, sources etc. This information is used for the analysis.

Fundamental Keywords

Table 1: List of Primary and Secondary Keywords

Fundamental Keyword	**"Behavior Prediction"**
Primary Keywords using (AND)	**"Autonomous Vehicle"**
Secondary Keywords using (OR)	**"Motion Prediction" "Trajectory Prediction" "Intelligent Vehicle" "ADAS" "Machine Learning" "Artificial Intelligence" "Explainable Artificial Intelligence" "Deep Learning"**

Thus the query for searching the documents in Scopus is:

(TITLE-ABS-KEY ("behavior prediction") AND TITLE-ABS-KEY ("autonomous vehicle") OR TITLE-ABS-KEY ("motion prediction") OR TITLE-ABS-KEY ("trajectory prediction") OR TITLE-ABS-KEY ("intelligent vehicle") OR TITLE-ABS-KEY ("ADAS") OR TITLE-ABS-KEY ("Machine Learning") OR TITLE-ABS-KEY ("artificial intelligence") OR TITLE-ABS-KEY ("explainable artificial

intelligence") OR TITLE-ABS-KEY ("deep

learning")) AND PUBYEAR > 2010 AND PUBYEAR < 2021

2.2 Initial Search Outcomes

On the Scopus database, using the different keywords related to our work, the publications are obtained. These are analyzed according to the language. It is found that, English language has the highest number of publications of 273 and 3 by Chinese language.

Table 2: Language Trends of Publications

Source: http://www.scopus.com (assessed on 04th Feb. 2021)

Language of publishing	Publication count
English	272
Chinese	3
Total	275

2.3 Publication outcome based on Top 15 Keywords

During the search, many keywords are found in addition to the fundamental keywords. Top 15 keywords are listed here in the table. Forecasting and behavior prediction are the keywords having the highest publications. Generally all these keywords are found to be related to traffic actors on highways and technology.

Table 3: Publication Analysis based on Top 15 keywords Analysis

Source: http://www.scopus.com (assessed on 04th Feb. 2021)

Sr. No.	Keyword	Publications
1.	Forecasting	147
2.	behavior prediction	105
3.	behavioral research	73
4.	machine learning	64
5.	artificial intelligence	63
6.	learning systems	56
7.	deep learning	40
8.	intelligent systems	27
9.	learning algorithms	23

10.	neural networks	21
11.	Vehicles	21
12.	intelligent vehicle highway systems	20
13.	Prediction	20
14.	social networking (online)	20
15.	Sales	18

III.   PERFORMANCE ANALYSIS

VOSviewer 1.6.16 [12][13] is the software that is used for the database analysis in addition to the analysis form Scopus. It provides a very effective way to analyze the co-citations, co-occurrences, bibliometric couplings etc.

Following types of analysis is performed.

Statistical Analysis of Databases

1. Documents by Source
2. Documents by year
3. Documents by subject area
4. Documents by Type
5. Documents by Country
6. Documents by author
7. Documents by affiliation
8. Documents by top funding agencies

Network Analysis of Databases

1. Co-authorship: Authors, organizations, country
2. Co-occurrence: All keywords, Author keywords, Index keywords
3. Citation Analysis: Sources, authors, organizations, country
4. Bibliographic coupling: Documents, Authors

IV.   RESULTS AND DISCUSSION

Analysis is performed by two different ways, statistical analysis of database and network analysis.

4.1 Statistical Analysis

4.1.1 Document Analysis by Sources

Database indicates different sources such as conferences, journal, book chapter, notes, and reviews and so on. Year-wise publication statistics are shown in the table. Figure shows the graphical representation of the different sources with number of documents published year-wise.
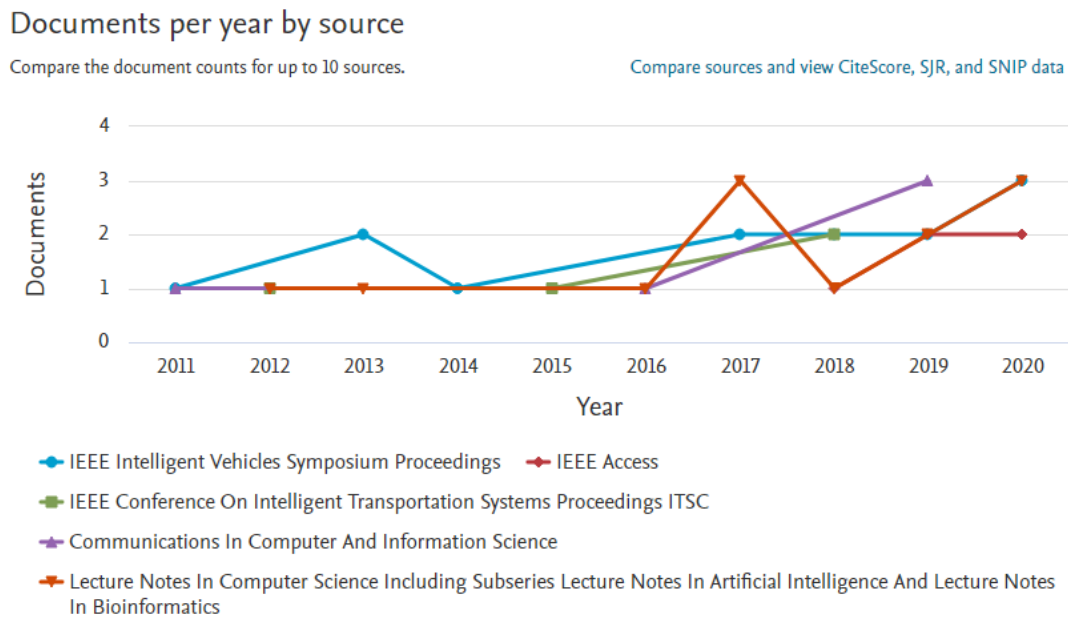

Figure 3: Analysis of Documents by Sources
Source: http://www.scopus .com (assessed on 04th Feb. 2021)

4.1.2 Documents Analysis by year

Documents are collected from scopus database in the year 2011 to 2020 including different sources such as conferences, journal, book chapter etc. The table shows the statistical information and graphical representation is as shown in figure. It is observed from the analysis that, highest number of publication is in the year of 2019 followed by 2020. This shows that, there is a good scope for working in this area in the preceding years.

Table 4: Number of Publication by Year
Source: http://www.scopus.com (assessed on 04th Feb. 2021)

Year	Number of Publications
2020	68
2019	67
2018	36
2017	30

2016	18
2015	17
2014	10
2013	12
2012	09
2011	08
Total	**275**
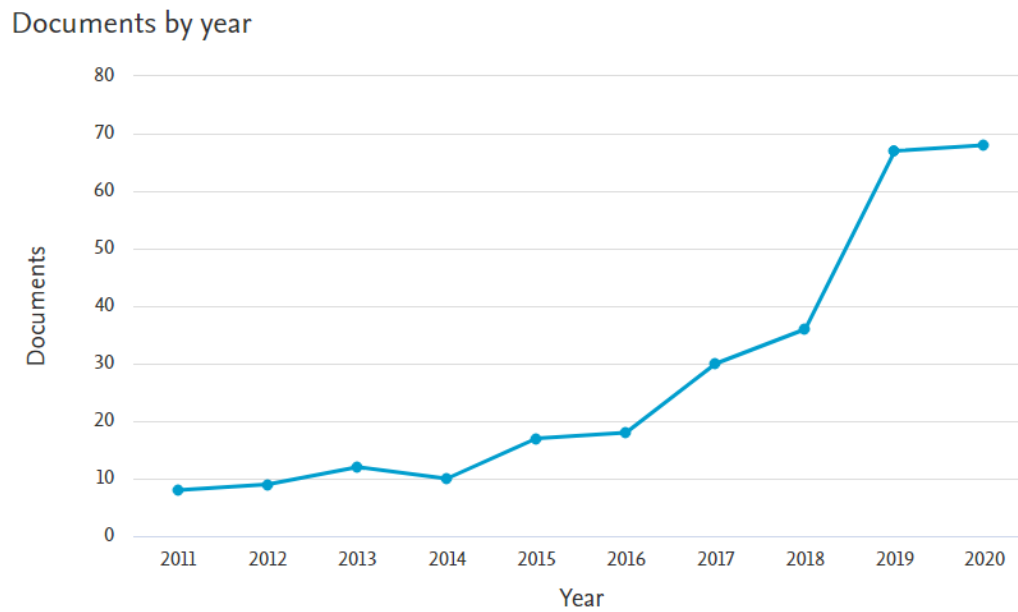
Documents by year

Figure 4: Analysis of Documents by Year

Source: http://www.scopus .com (assessed on 04th Feb. 2021)

4.1.3   Documents by Subject Area

Behavior prediction for autonomous vehicle is done through video analysis and machine learning algorithm. Hence for the prediction for vehicle and pedestrian behavior, maximum papers are coming under computer science (37.2%) and engineering field (20.7%). The main reason for this is, the topic is related to computer science and Engineering.

Documents by subject area
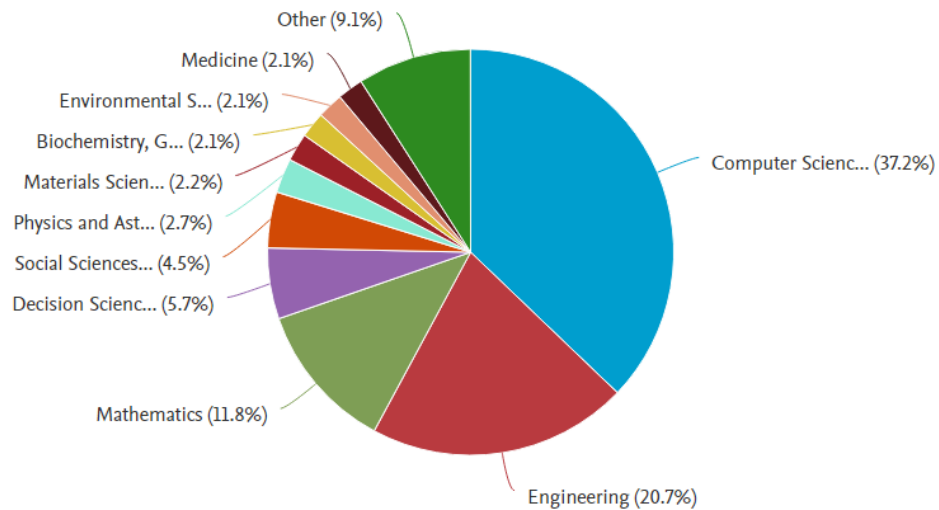
Figure 5: Analysis of Documents by Subject Area

Source: http://www.scopus .com (assessed on 04th Feb. 2021)

4.1.4. Documents by Type

It is seen form the analysis that, most of the publications are journal articles followed by conference papers.

Table 5: Analysis by Document Types

Source: http://www.scopus .com (assessed on 04th Feb. 2021)

Sr. No.	Document type	Publications
1.	Conference Paper	171
2.	Article	84
3.	Conference Review	10
4.	Book Chapter	5
Total		**275**

Documents by type
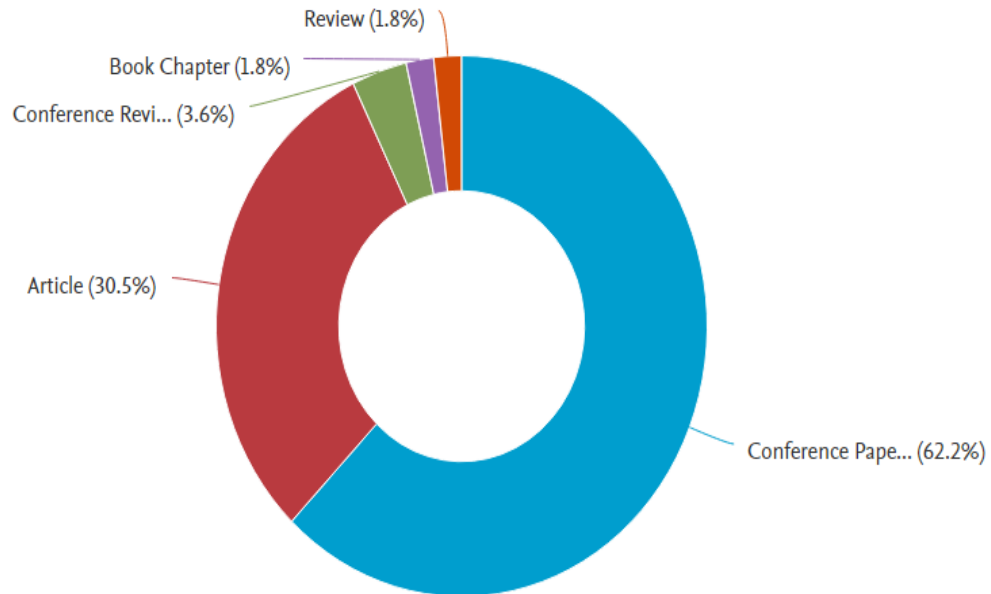
Figure 6: Analysis of Publications by Document Type

Source: http://www.scopus .com (assessed on 04th Feb. 2021)

4.1.5   Analysis of Publications by Country or Territory

Scopus database is analyzed for countries by considering the number of documents published. It shows that United States has the highest number of documents published between the elected timeline. It is followed by China and then Germany.

Documents by country or territory
Compare the document counts for up to 15 countries/territories.
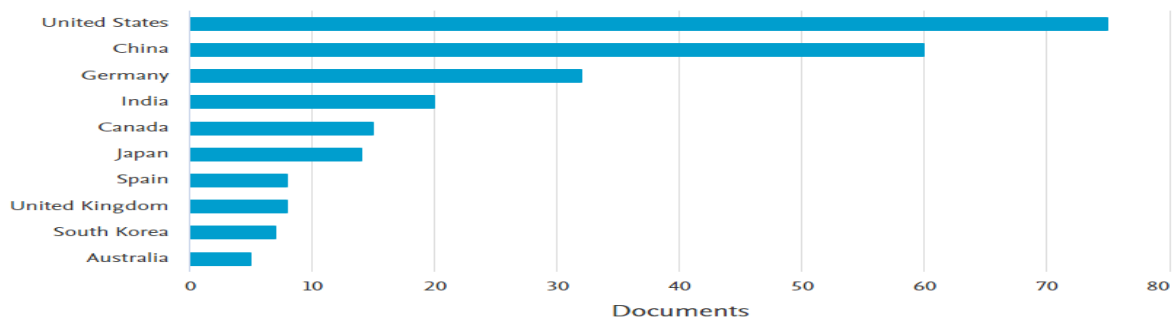
Figure 7: Analysis by Country

Source: http://www.scopus .com (assessed on 04th Feb. 2021)

4.1.6 Documents by Author

In this analysis, authors with the number of publications are considered. Publications with a very large number of authors (15) are excluded. Top 10 authors with this comparison are shown here. It is found that Dou D. has the highest number of publications of 8 in this area. Maximum authors have an approximate average publication count 3 to 6.
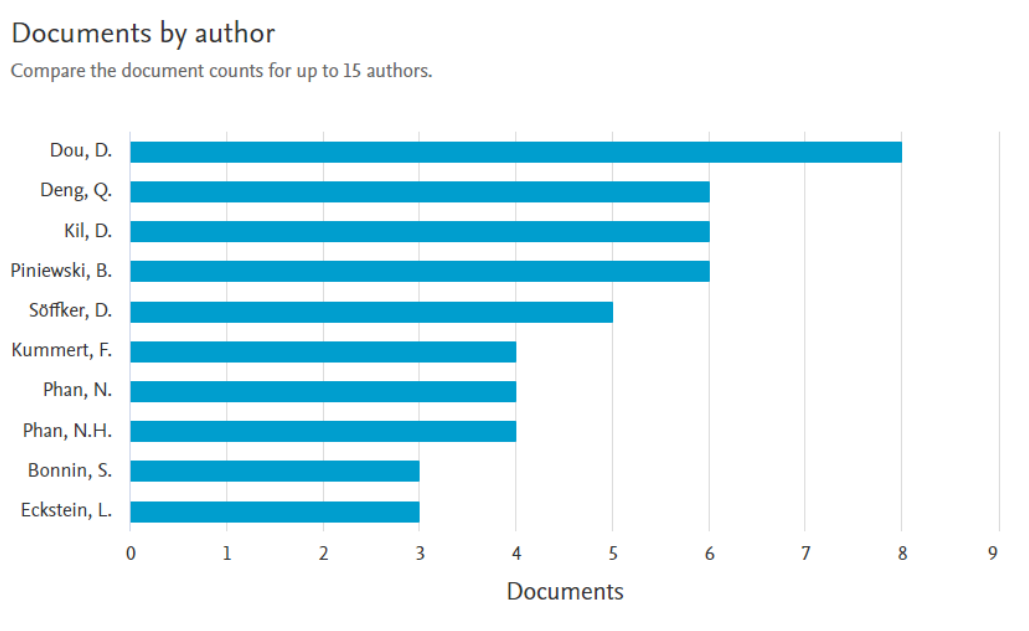

Figure 8: Analysis of Documents by Author
Source: http://www.scopus .com (assessed on 04th Feb. 2021)

4.1.7 Documents by Affiliations

In this analysis, top 10 affiliations are considered. More than half of the affiliations have at least 4 publications related to this field.

Documents by affiliation
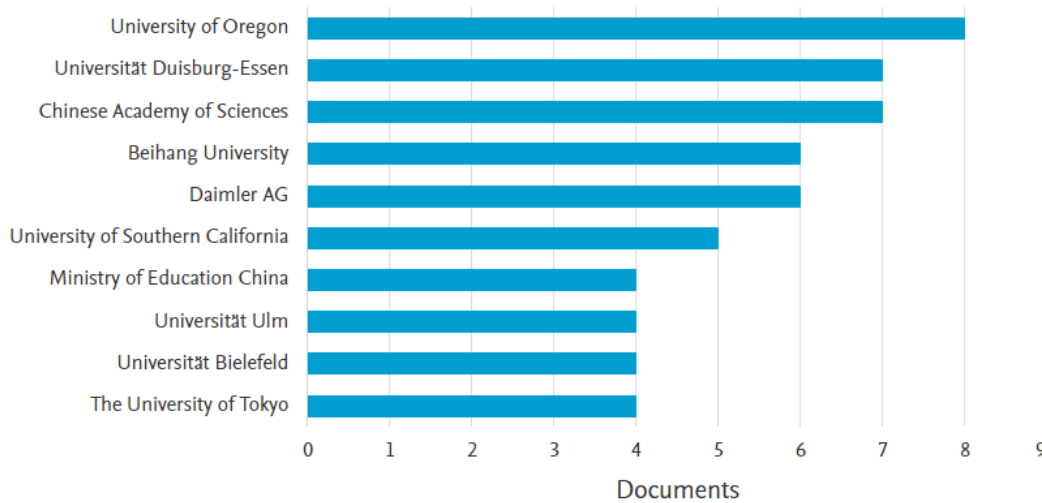Compare the document counts for up to 15 affiliations.

Figure 9: Analysis of Documents by Affiliation

Source: http://www.scopus .com (assessed on 04ᵗʰ Feb. 2021)

4.1.8 Analysis by Funding Sponsors

In this case, China is ahead amongst all, with highest funding to the National Nature Science Foundation, China.

Documents by funding sponsor
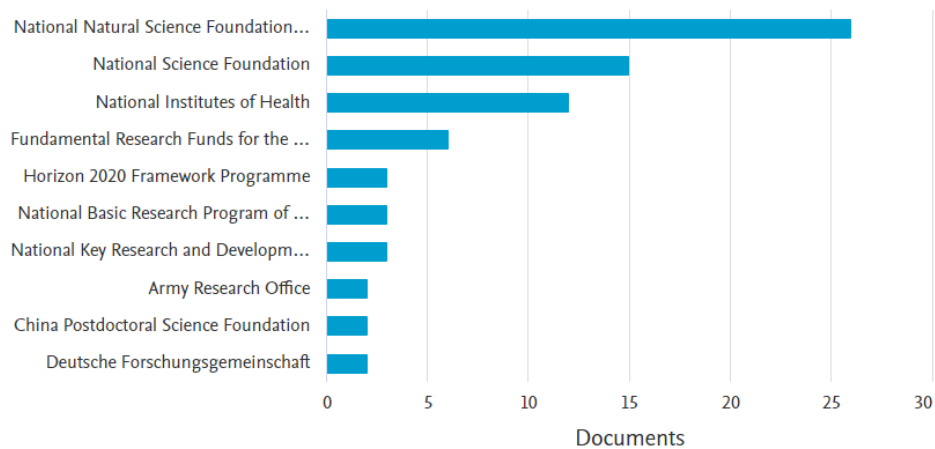Compare the document counts for up to 15 funding sponsors.

Figure 10: Analysis of Documents by Funding Sponsor

Source: http://www.scopus .com (assessed on 04ᵗʰ Feb. 2021)

4.2 Network Analysis

4.2.1 Co-authorship Analysis

A) Co-authorship in terms of Authors

This parameter of analysis is considered with 03 different parameters related to it. The authors, organizations, and countries are considered for analyzing this parameter.

Documents with a very large number of authors are ignored in this analysis. This number is considered to be 25. Threshold is considered as 2 for minimum number of documents of an author.

It is seen that out of 857 authors, 105 authors met the criteria. The total strength of the co-authorship is calculated with other authors. By this method, the link strengths are obtained. Dou d., found the highest link strength of 26 with the total number of citations to be 177 for 08 different documents. Here total of 61 authors found to have the relation in terms of co-authorship. So these are only shown in the figure.
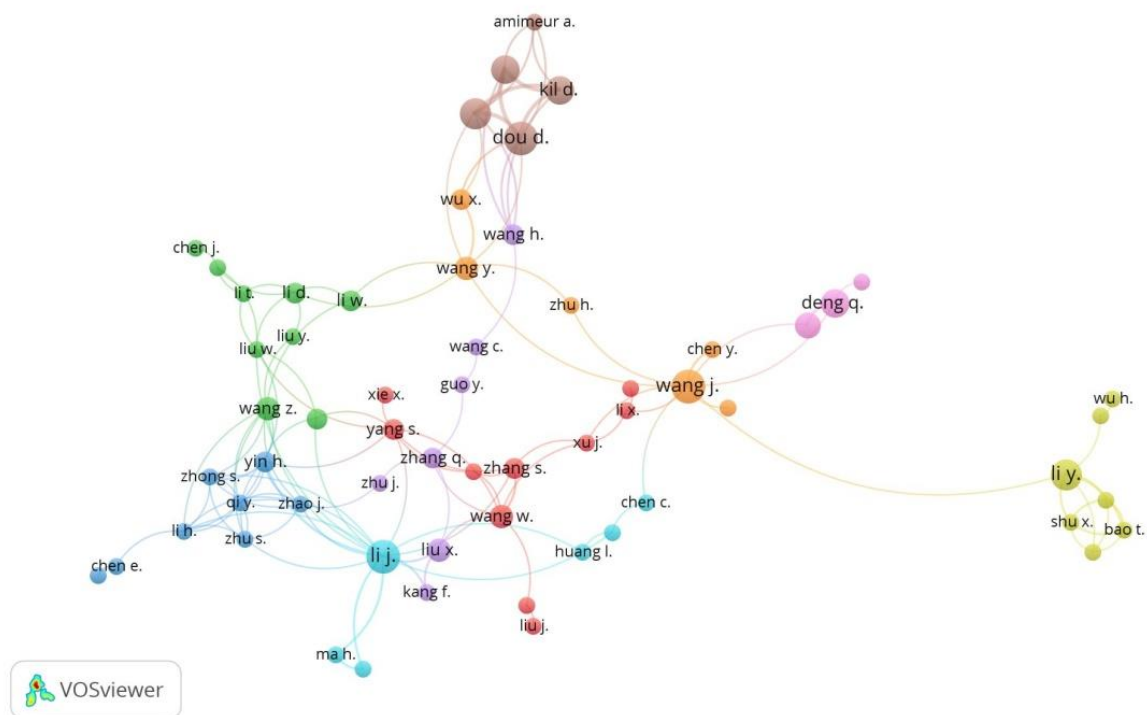

Figure 11: Co-authorship Network Analysis in Terms of Authors

Source: http://www.scopus .com (assessed on 04th Feb. 2021)

B) CO-authorship in terms of Organizations

Co-authorship in the unit of organizations is calculated considering minimum 02 documents in organizations with neglecting the citation of the same, 23 organizations meet the criteria

out of 512 numbers of total organizations that are shown in the figure. A total of 2 organizations have highest link strength of 6 with the highest citations of 93 by university of Oregon, United States (with 4 documents).
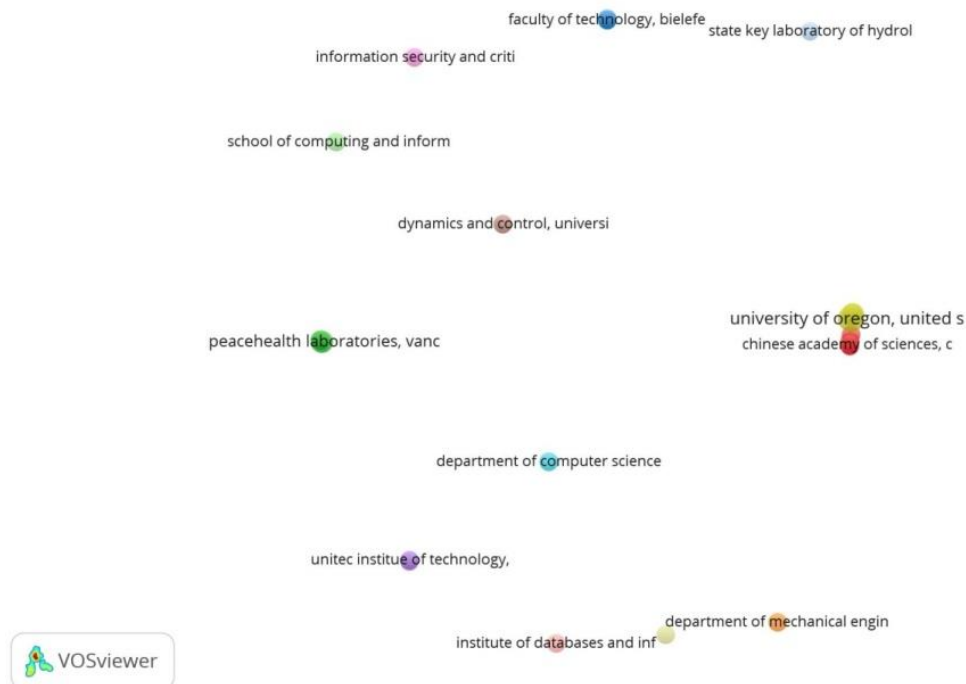

Figure 12: Co-authorship analysis in terms of Organizations

Source: http://www.scopus .com (assessed on 04th Feb. 2021)

C) Co-authorship in terms of Country

Co-authorship can also be obtained in relation to the country. A total of 56 countries are there, in which this databases are present. After considering the threshold of minimum 5 documents in a country, 12 countries met the threshold.

Here, United States found to have the highest citations of 1108, and the link strength of 26, that is also highest amongst all. As far as the number of document is concerned, United states has the highest of all that is 74.
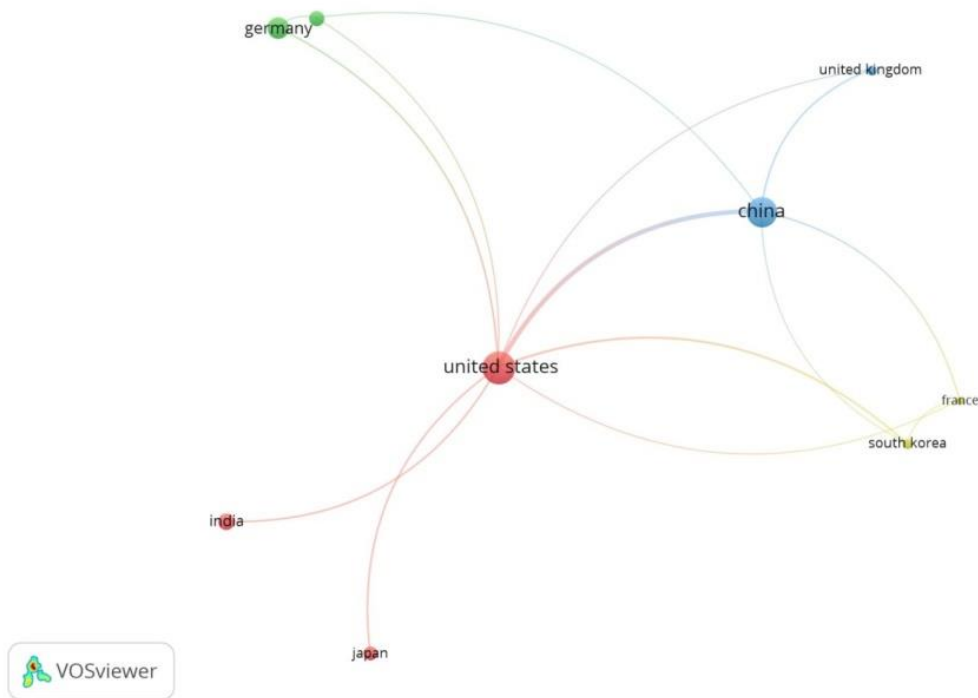
Figure 13: Co-authorship analysis in terms of Countries (Scale is with number of documents)

Source: http://www.scopus .com (assessed on 04ᵗʰ Feb. 2021)

4.2.2. Network Analysis of Co-occurrences

A) Co-occurrence analysis in terms of all keywords

For the analysis of co-occurrences, different keywords are considered. Minimum number of occurrences in the keywords is considered to be 5. Out of 2469 keywords, 99 keywords met the threshold.
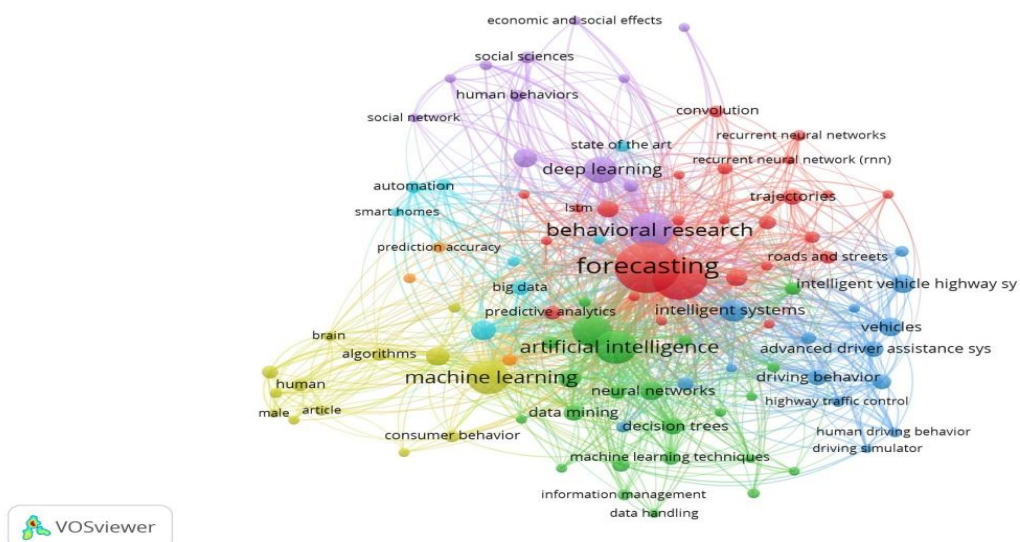

Figure 14: Co-occurrence Analysis in Terms of All Keywords

Source: http://www.scopus .com (assessed on 04ᵗʰ Feb. 2021)

B) Co-occurrence analysis in terms of Author keywords

Co-occurrence of author keywords is analyzed with the minimum threshold of 5 per author. Out of 699 keywords by the authors, 10 keywords met the threshold.
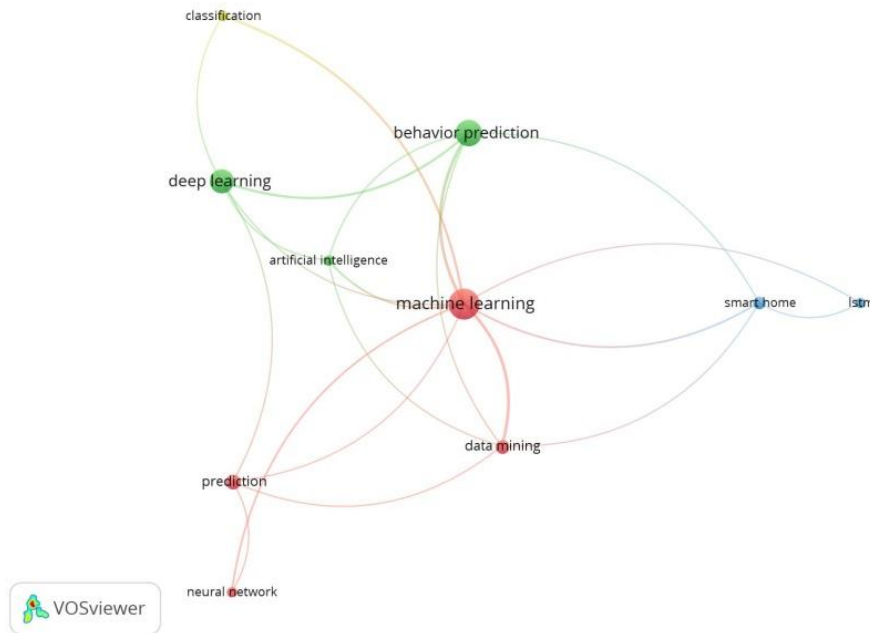

Figure 15: Co-occurrence Network Analysis (Author Keywords)

Source: http://www.scopus .com (assessed on 04th Feb. 2021)

C) Co-occurrence in terms of Index Keywords

Co-concurrence is also considered by index keywords of 2064, only 90 met the threshold.
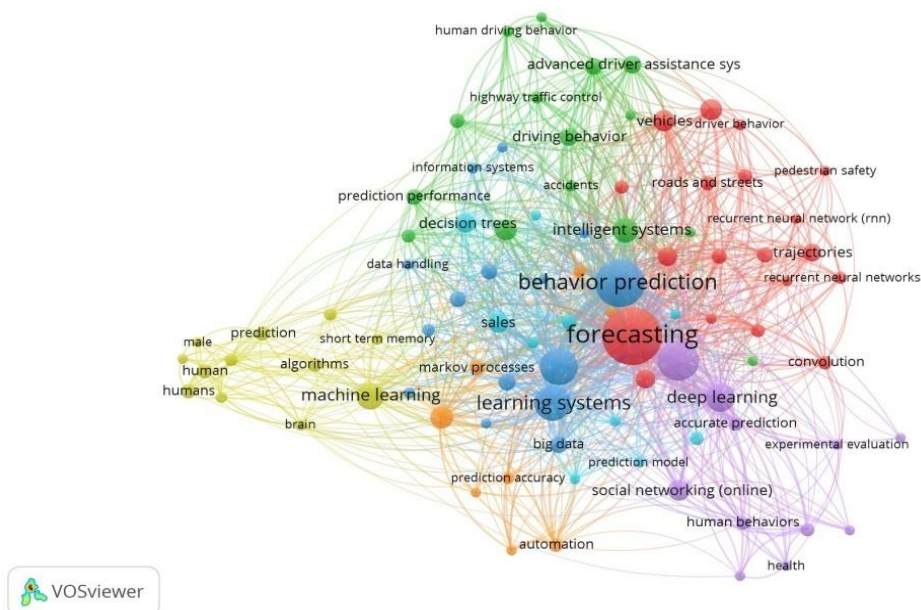

Figure 16: Co-occurrence of Index Keywords

Source: http://www.scopus .com (assessed on 04th Feb. 2021)

4.2.3. Network Analysis of Citations

This analysis is done with the units of analysis including documents, sources, authors, country and organization.

A) Citation Analysis of Documents

Out of total of 275 documents, minimum 5 citations are considered as a threshold per document. So 73 documents met the threshold. Chen M. (2017) has the highest number of citations 352 while the link strength for Gao M (2018) and Phan n.h. (2017)   are 1 which is highest.
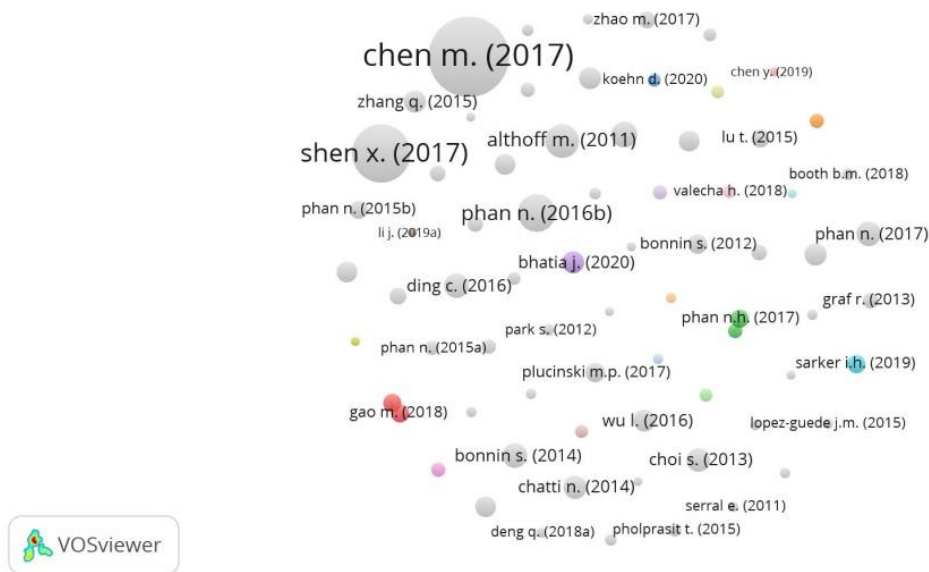

Figure 17: Network Analysis of Citations (In terms of Documents)

Source: http://www.scopus .com (assessed on 04ᵗʰ Feb. 2021)

B) Citation Analysis of Sources

Citation analysis of sources is obtained by considering the threshold of 5 citations per source. Out of the 204 sources only 04 met the threshold. IEEE intelligent vehicle journal has got maximum citations of 113.

Figure 18: Network Analysis of citation by sources,

Source: http://www.scopus .com (assessed on 04th Feb. 2021)

C) Citation analysis by Authors

Threshold considered here is 3 citations per author. A total of 25 authors met the threshold amongst the total of 857 authors. Dou d. has maximum citations of 177.
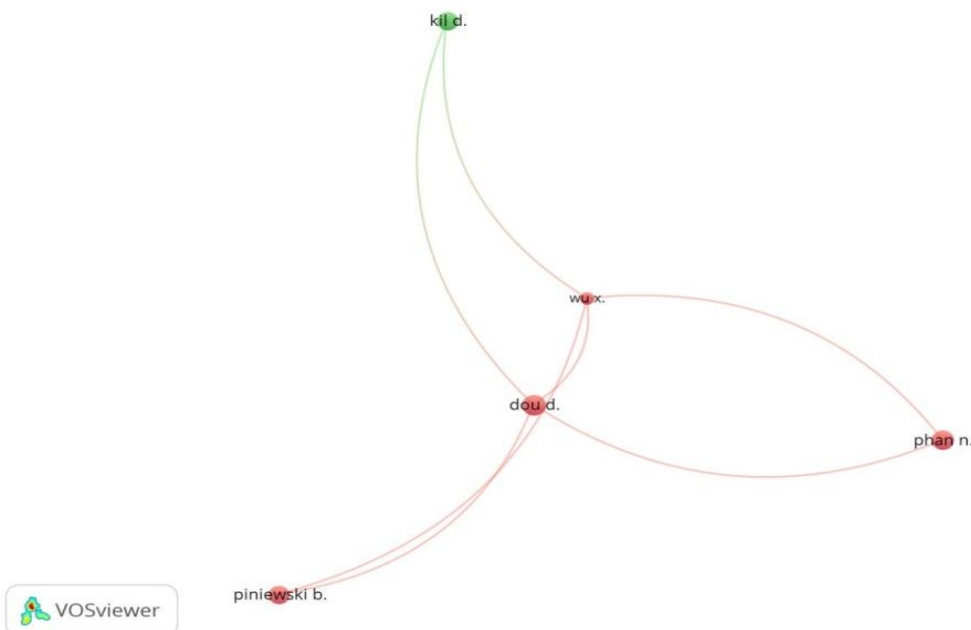

Figure 19: citation analysis by Authors,

Source: http://www.scopus .com (assessed on 04th Feb. 2021)

D) Citation analysis by organization

Considering minimum documents of 3 per organization as threshold, 3 organizations met the threshold out of 512 organizations. University of Oregon, United States has Maximum citations of 93.

Figure 20: Citations by Organizations,

Source: http://www.scopus .com (assessed on 04th Feb. 2021)

E) Citation analysis by country

Total of 56 countries have the databases of the behavior prediction work. Out of which 12 met the citation criteria considering a threshold of minimum 5 citations per country.
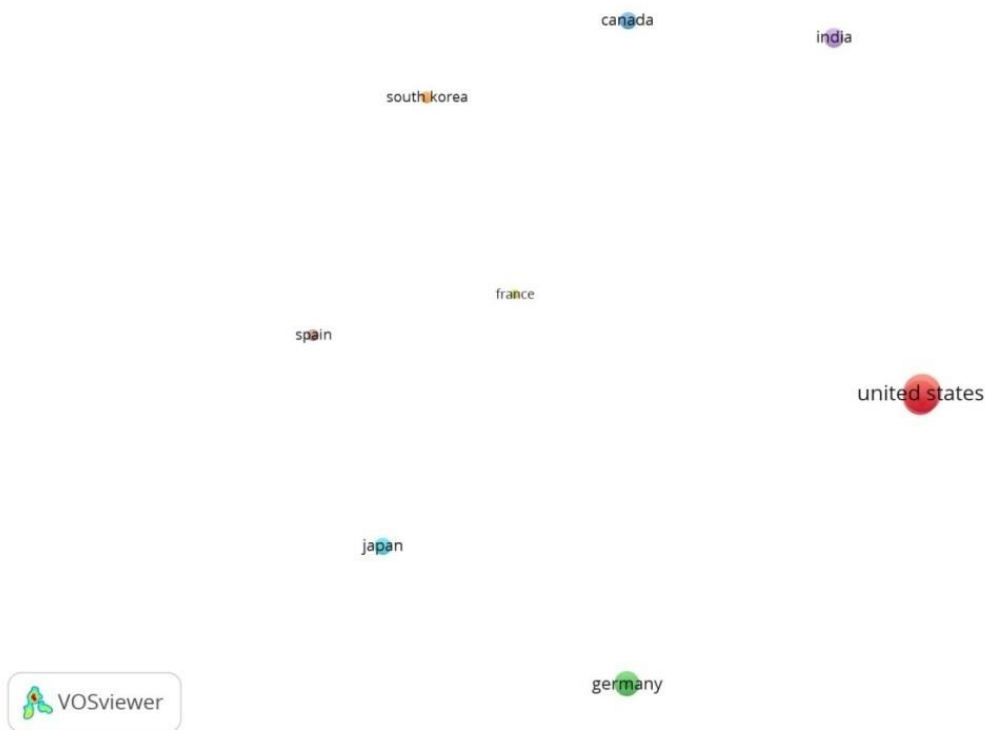
Figure 21: Citation analysis of country,

Source: http://www.scopus .com (assessed on 04th Feb. 2021)

4.2.4. Network Analysis of Bibliographic Coupling

A) Bibliographic Coupling of Documents

Considering, 3 citation of documents as a minimum threshold value. Out of total 275 documents, 103 authors met the threshold criteria.
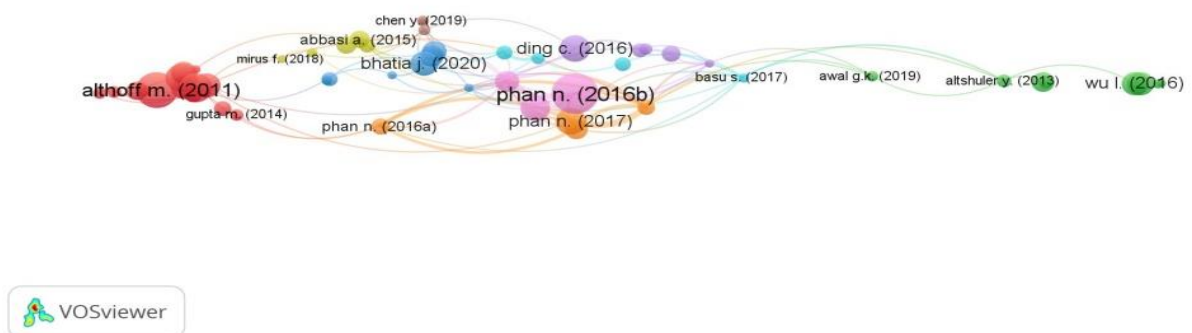

Figure 22: Bibliographic coupling of documents,

Source: http://www.scopus .com (assessed on 04th Feb. 2021)

B) Bibliographic coupling of Authors

Considering, 3 documents per author as a minimum threshold value. Out of total 857 authors, 25 authors met the threshold criteria.
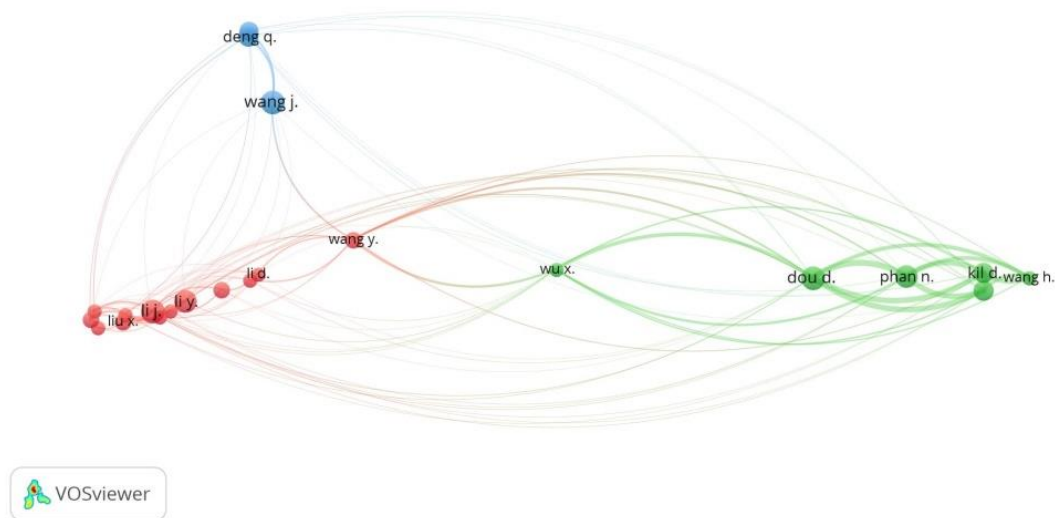

Figure 23: Bibliographic coupling of Authors,

Source: http://www.scopus .com (assessed on 04th Feb. 2021)

V.   CONCLUSION

The most common and largest database used worldwide, Scopus, conducts a bibliometric survey on behavior prediction for autonomous vehicles through machine learning and deep learning. The database is being considered for the period from 2011 to 2020. The database search is achieved by using a keyword search with an AND operator and an OR operator. A total of 275 documents are obtained as the outcome of the search.

The different parameters are considered for analysis of this database. It is seen that English language has most of the documents 272 followed by Chinese documents 3.The outcome of Keyword search indicates that maximum publications are with the keyword "*forecasting* " *and "behavior prediction".* Maximum documents are published in the year 2019 followed by the year 2020.The subject area Computer Science and Engineering covered almost 53% of the documents. As far as, the type of document is considered, conference papers are the major occupants followed by the article of journal. The analysis of countries proved, United States as the highest number of documents within the period.

Documents by different authors also analyzed and maximum author's average Publications

account 3 to 6.The highest number of documents is from University of Oregon and China is the highest funding sponsor in this area.

The network analysis is also done by VOSVierer 1.6.16 version software. The different analysis types such as co-authorship analysis co-occurrence analysis citation analysis and bibliographic coupling are done with the same database. All these different network analysis indicates a quite significant information about different mentioned above. It could also be seen that the major work in behavior prediction for autonomous vehicle is done in 2019 and 2020. In upcoming years a very vast and major work is expected in this area.

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