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Bibliometric analysis on Hand Gesture Controlled Robot

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Abstract

This paper discusses about the survey and bibliometric analysis of hand gesture-controlled robot using Scopus database in analyzing the research by area, influential authors, countries, institutions, and funding agencies. The 293 documents are extracted from the year 2016 till 6th March 2021 from the database. Bibliometric analysis is the statistical analysis of the research published as articles, conference papers, and reviews, which helps in understanding the impact of publication in the research domain globally. The visualization analysis is done with open-source tools namely

GPS Visualizer, Gephi, VOS viewer, and ScienceScape. The visualization aids in a quick and clear understanding of the different perspective as mentioned above in a particular research domain search.

Keywords: Hand-gesture, robots, robot arm, flex sensors, gesture recognition.

1. Introduction

Hand gesture-controlled systems have emerged to be one of the most anticipated fields of research in the recent years. Its wide range of possible applications makes it a very powerful feature in various fields such as robotics, surgery, etc., also in the recent time of Covid-19 pandemic it also has a scope of being implemented to develop contactless treatments and tests. It has the scope of achieving precision that a human hand cannot. Hand gesture recognition is one of the emerging fields of technology in the field of human-computer interaction. It has a wide variety of applications in daily life activities and workspaces (Salman et al., 2020). Hand gesture recognition can enable humans to interact with machines without using traditional hardware devices such as keyword and mouse (Fan et al., 2016). Hand gestures are of two types, static and dynamic,static hand gesture are static postures of hands and their gestures, and dynamic hand gesture is defined by dynamic movement of hand and arm (F. Chen et al., 2018). People with physical disabilities have found it difficult to get habitual to human computer interaction devices which involve external devices, by hand gesture one can easily interact with systems without any external devices (Sriram & Palaniswamy, 2019), such devices also prove themselves to be helpful for paralysis patients for whom moving from one place to another is something out of their limits (Dutta et al., 2018) . Although hand gesture recognition is a promising field of study, it still cannot effectively capture the minor detailed movements, also it is limited to short range which makes it even more difficult to capture complex gestures (Yuan et al., 2021). Gestures also play a vital role in applications of Virtual Reality(VR) and Augmented Reality(AR) (Chuang et al., 2019).

A large part of the world population suffers from inability of verbal communication, they find themselves in a difficult situation while trying to communicate with others. Mehra et al., 2019 have proposed a system that can convert gestures to speech for the people who cannot speak, so that they can communicate with ease.The above mentioned model is based on flex sensors to capture finger gestures, also for the controlling unit Arduino uno has been used.Matlab has been used for image processing, after image processing a machine learning algorithm has been used for gesture recognition which will recognize the gesture and match with the dataset that it has been trained on and then a text will be generated corresponding to the gesture.This ambitious project can be a big relief for people with verbal impairments as they no longer have to rely on a translator to commicate with the world.

A hand gesture recognition sensor has been implemented to regulate the arm mounted on a robot utilized in underwater applications (Mardiyanto et al., 2017). The elbows, forearms and wrist of the manipulator are loaded with accelerometer and gyroscopes-based sensors. The position of each joint is determined by means of kinematics and these positions are sent to the robot hand. The laboratory results of the above-mentioned project showed 98% accuracy.

Telluri et al., 2020 propose a system that can recognize hand gestures using flex sensors, Arduino, and Bluetooth and determine the alphabetical character corresponding to the gesture for people with speech and hearing impairments, to be able to communicate easily with those who cannot understand sign language. The structure of the system is such that the user will be wearing a glove loaded with multiple flex sensors which are connected to a microcontroller or microprocessor present on the glove itself. The signals generated by flex sensors are sent to the microprocessor or microcontroller to compute the results that will determine what kind of gesture is being performed by the user. The character corresponding to the gesture as computed by the processor is transmitted to a display connected to the glove via Bluetooth and this character is displayed. In the above-mentioned system, the ability of the flex sensors to be able to measure physical stress and stain lays the foundation of gesture recognition. Human-Computer interactions become more convenient and effective when the robots can properly understand human intentions, hence how robots correctly interpret human intentions using gesture recognition is a very important factor to improve such interactive systems (Li, 2020).

Research was conducted by (Puruhita et al., 2020) to develop a humanoid robot hand that can mimic human hand movements, like grasping an object, opening, and closing. The movement of the hand depends on Degrees of Freedom (DOF) which determines how many movements can the robot hand perform in total. The above-mentioned robot was designed by using 5 servo motors to control the movement of the robot fingers and two stepper motors to control the robot arm. The movements of the fingers of the robot are captured using flex sensors and the movements of the robot arm are captured by potentiometer.

Flex sensors play a major role in gesture recognition. As per research conducted by (Setiawan et al., 2020), flex sensor is a sensor that works to detect curvature. The voltage divider circuit is used as a circuit to convert the changes in resistance value into the voltage changes when the flex sensor is bent. Voltage divider circuit is a circuit in which the total input voltage is divided among the components of the circuit and the output voltage thus produced is a fraction of the input voltage. The limitation of this type of sensor is that the bend can only be detected in one direction (Mubarak A. & Ahmad, 2020). As per study conducted by (Bhuyan et al., 2020) induction coils can be used as an alternative to flex sensors. They have implemented a data glove for hand gesture recognition using induction coils. The Author uses the idea of measuring the hand gestures or the hand motion, using the concept of induction coils, to be used as sensors. These induction coils would be placed in the data glove. The steps follow this idea, by determining the angle between the finger joints and accordingly recognizing the corresponding gesture performed by the user. As per the author, there are various ways to extract data from the hand gestures, which are measured by calculating the angles between the finger joints.The signals are generated using the concept of Resonant Inductive Coupling,according to Faraday’s law of Electromagnetic induction when two conductors are placed adjacent to each other and one of the conductors is conducting current it induces current in other conductor due to the electromagnetic waves possessed by the former conductor. The author also talks about how interference is caused by EM fields generated by different generator coils. This major problem can be tackled by using the concept of FDM (Frequency Division Multiplexing) and TDM (Time Division Multiplexing). When we use TDM and FDM both, it is quite effective as compared to when we use only TDM. The Data glove will contain the generator coils, Demux and an Analog Mux, through which the signal will be transmitted to the offhand module of the system. Signal will be given to an Amplifier here, Band Pass filters and then through a Mux and an ADC, the signal passes to a Microcontroller to give the output, which will be serially connected to a PC.

All the above-mentioned projects involve a robot connected to the control unit by means of wireless communication. To transmit data using wireless transmission and control the robot arm using wireless transmission, a wireless module is required (Liu & Pei, 2020). They have implemented a wireless bionic manipulator using NRF24L01 wireless transmission module. It has an operating frequency of 2.4 GHz. This module follows duplex communication, meaning, it can transmit and receive data at the same time, also it can transmit data over a range of 1000m and can connect to multiple systems at the same time allowing to control more than one robots simultaneously (Bakri et al., 2019). A wireless module also called as RF module is a combination of transmitter (Tx) and a receiver (Rx). This module is avaible in different opetrating frequencies and different operating ranges (Aggarwal et al., 2013). Wireless communication allows a system to operate while their control units are stationarily placed at some place. A reconfigurable wireless controlled robot has been implemented using ZigBee wireless communication separating control boxes and robot arms, and the arm and the controller run on independent power source, improving the overall flexibility of the robot (Xu et al., 2021).A Zigbee module communicates within the range of 50m (Jose et al., 2016).

Añazco et al., 2021 have implemented hand gesture recognition using Single Patchable Six-Axis Inertial Measurement Unit (IMU) and RNN (Recurrent Neural Network). The micro six-axis sensors transmit inertial signals according to the movement of the attached skin using the two-wired serial interface. In the micro six-axis sensor, three-axes accelerations and three-axes rotational velocities are digitized by the built-in 16-bit analog-to-digital converter (ADC). These converted inertial signals are passed through the bus interface unit 400 kHz I2C communication (a communication protocol). IMUs tend to be more complex and sophisticated compared to flex sensors, also flex sensor has its own limitations. As per the study conducted by (Mohamed & Lin, 2016) If we were to incorporate the rotation of the whole arm about its own axis it is not possible to implement using flex sensors, IMUs prove themselves to be more efficient in such cases as they can measure angular rate, force, and sometimes magnetic fields. An IMU provides 2 to 6 DOF (Degrees of Freedom), which refers to the number of possible movements in 3D space (Pao, 2018).

Implementing hand gesture control of a robot requires encoding of the hand gestures to a particular movement of the robot, for that we need to have logical implementation, for the microcontroller to understand what kind of instructions it is supposed to give to the robot to make it move in a particular manner. To encode the gestures (Sihombing et al., 2020) have implemented 'Fuzzy Logic'. Fuzzy logic has been used in the processing of the flex sensors and MPU-6050 sensor which is based on degree of slope of the x-axis and the y-axis (The glove is loaded with MU-6050 sensor to control the angular movements of the robot. The MPU-6050 sensor is used to control the upper rma and the shoulder of the robot). Figure 1 shows the 'Fuzzy Logic' thus implemented.

TABLE I. THE IMPLEMENTATION OF FUZZY LOGIC IN THE ROBOT HAND CONTROLLER

Sensor	Range	Value	Code	Explanation
MPU-6050 angle x	1_gyroX	≤-5	'0'	Turn shoulder to the right
MPU-6050 angle x	2_gyroX	≥25	'1'	Turn shoulder to the left
MPU-6050 angle y	1_gyroY	≥25	'2'	Move the upper arm up
MPU-6050 angle y	2_gyroY	≤-40	'3'	Move the upper arm down
Flex index finger	1_flex1	<160	'4'	Move the lower arm up
Flex index finger	2_flex1	>160 and <200	'5'	Move the lower arm down
Flex middle finger	1_flex2	>250	'6'	Move the wrist up
Flex middle finger	2_flex2	>250 and <280	'7'	Move the wrist down
Push Button	pressed	1 (active)	'8'	Open the gripper
Push Button	no pressed	0 (not active)	'9'	Close the gripper

Figure 1: Implementation of Fuzzy logic

Servo motors power the joints of a robot. (Amari et al., 2020) have discussed about servo motors and how they have implemented a three fingered robot hand using SG90 and MG996R motors. Due to small size of SG90 motors they chose to use it for finger and thumb joints, also as per their research each SG90 servo motor has a torque of 2.5kg.cm which is a "descent torque for the grip of the arm". The elbow joint handles greater load compared to any of the joints in the forearm so MG996R has been used for the elbow joint as it has a torque of 10kg.cm which is apparently optimal for elbow joint to handle heavy load, followed by the shoulder joint which deals with even greater load, MG946R motors have been used with a torque of 13kg.cm. It is evident from the above discussion that the choice of motors for joints depends on the load they are meant to deal with.

Leap motion sensor is an optical device used to interact with the computer. It consists of three infra-red LEDs and two cameras. Leap motion sensors have proven themselves to efficient and reliable device for implementation of human machine interfaces (Milojević, 2018).The Leap Motion can capture movements of hands,fingers, including the individual bones of fingers, all in 6 DOF.The sensor can capture maximum 200 frames per second(FPS) (Devine et al., 2016). Chen et al., 2018 have implemented gesture control of a SCARA robot using Leap motion sensor. They state that “Leap Motion Controller is a desktop contactless interactive device that captures gesture data through infrared imaging principles, so external interference will not affects the operation of the application, and the accuracy can reach 0.01mm”.It is a better alternative for flex sensors but much more expensive comparatively.In its active mode a leap motion sensor can detect any movement of gesture in its field of vision (Oguntosin et al., 2019) .Just like Leap motion sensors ‘Kinect Sensors’ can efficiently detect hand motions and incorporate for various functions of robot.Kinect sensor was introduced by Microsoft in June 2010.It is a depth camera which consists of two cameras(Video Camera and other is IR camera) and one IR projector.One camera gives RGB image and other determines the distance of individual objects in the scope of camera. IR projector is used as a IR light source, the IR projector projects laser patterns towards the objects which are bounced back and are captured by IR camera and the depth of the image is determined. Pal & Kakade, 2016 have implemented hand gesture recognition using Kinect sensor.

Till now we have discussed about implementation of hand gesture-controlled systems using sensors and other electronics hardware. Computer Vision is amongst the most trending fields of studies across the world, many studies have been developed advocating the possibility of developing a hand gesture-controlled robot using Computer vision. (Deepan et al., 2015) propose a robotic hand which will mimic human hand gestures and will be controlled by motion detection using Open-CV (Computer Vision) and Image filtering algorithms. The user sits in front of the camera with their palm facing towards the camera then the face of the user is filtered out using face subtraction algorithm while the video is being captured and the complete focus of the of the software is on the user’s hand. The motion detection algorithm then calculates the centroid of the palm and the points of the tip of the fingers(basepoints), as the user moves his or her fingers the distance between the centroid and the base points changes and the servo motors are controlled according to this changing distance of each finger by raspberry-pi processor. Many such algorithms are being developed and the performance of the robot depends on the accuracy of the co-ordinates determined by motion detection algorithms.

2. Preliminary Data

This paper has been prepared with the help of Scopus database. The database is a collection of wide variety of documents related to fields domains like engineering, energy science, materials science, computer science, physics, environmental science, and economics. The data has been fetched from Scopus database on 6th March 2021.The top ten keywords used to fetch the data have been tabulated below in Table 1. As per the analysis of the citation report, ‘Gesture Recognition’ is the most used keywords with a citation in 96 papers.

Table 1: Top 10 Keywords

Keywords	**Number of publications**
Gesture Recognition	96
Palmprint Recognition	62
Hand Gesture	59
Hand-gesture Recognition	56
Flex Sensor	42
Robotics	35
Robotic Arms	32
Human Computer Interaction	28
Wearable Sensors	28
Wireless Local Area Networks (WLAN)	22

Further Table 2 contains the data of types of publications and the number of papers that belong to these types. Out of 293 documents taken for analysis 168 are conference papers, 92 are articles, 27 are conference reviews, 1 book chapter, 1 review and 1 Short survey.

Table 2: Types of publications

Document Type	Number of publications
Conference Paper	168
Article	92
Conference Review	27
Book Chapter	4
Review	1
Short Survey	1

Table 3 shows the linguistic distribution of research published in this area. Out of 293 publications 290 are in English, 2 are in Chinese, and the last one is in Spanish. Therefore, English is the most prominent language across all publications taken for analysis.

Table 3: Linguistic distribution

Language	Number of publications
English	290
Chinese	2
Spanish	1

2.1 Preliminary data analysis

Figure 1 shows the data for number of documents published per year that share the same domain as this paper or are related to this paper. Since 2016 the number of publications published per year increased significantly and the maximum number of publications were published in 2019, approximately 70. Till now there are 10 publications in 2021.

Figure 2 shows the number of documents published by different sources per year from 2016 to 2021. “IEEE Access”, “Sensors Switzerland”, “Advances in Intelligent Systems and Computing”, “ACM International Conference Proceeding Series” and “Lecture Notes in Electrical Engineering” are the top five sources publishing in this research domain.

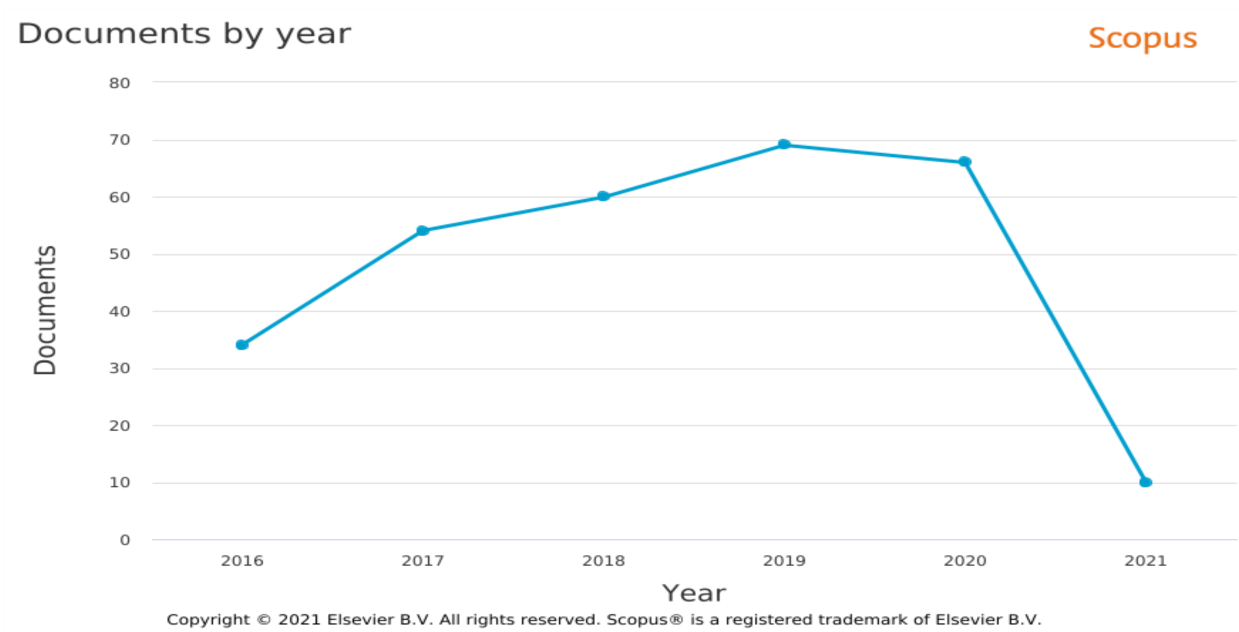

Figure 2: Documents published per year.

Figure 3 shows the documents published per year by source.

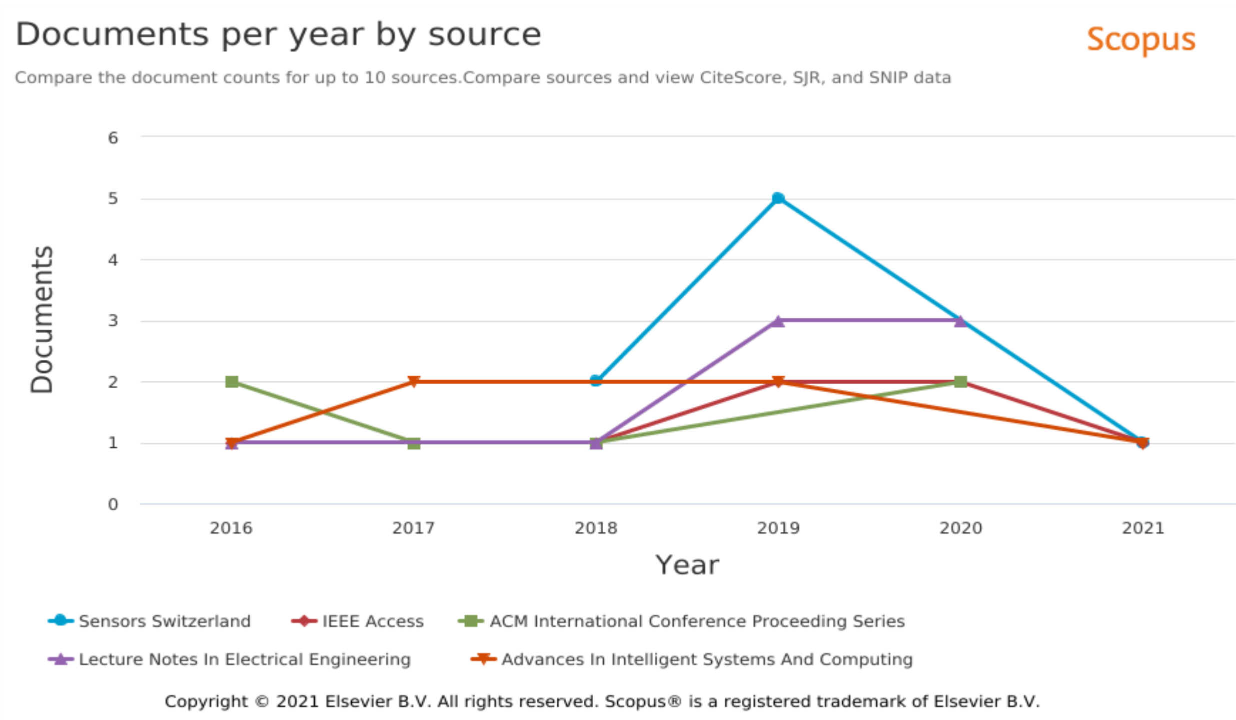

Figure 3: Papers published per year by sources.

Table 4: Top 10 countries

Country	Number of Publications
India	69
China	47
United States	37
Canada	13
South Korea	13
Taiwan	13
Australia	10
Malaysia	10
Japan	9
Bangladesh	8

Table 4 shows the data for top 10 countries with publications in this research domain. The greatest number of publications have been done in India with 69 publications, followed by China, the United States, and others.

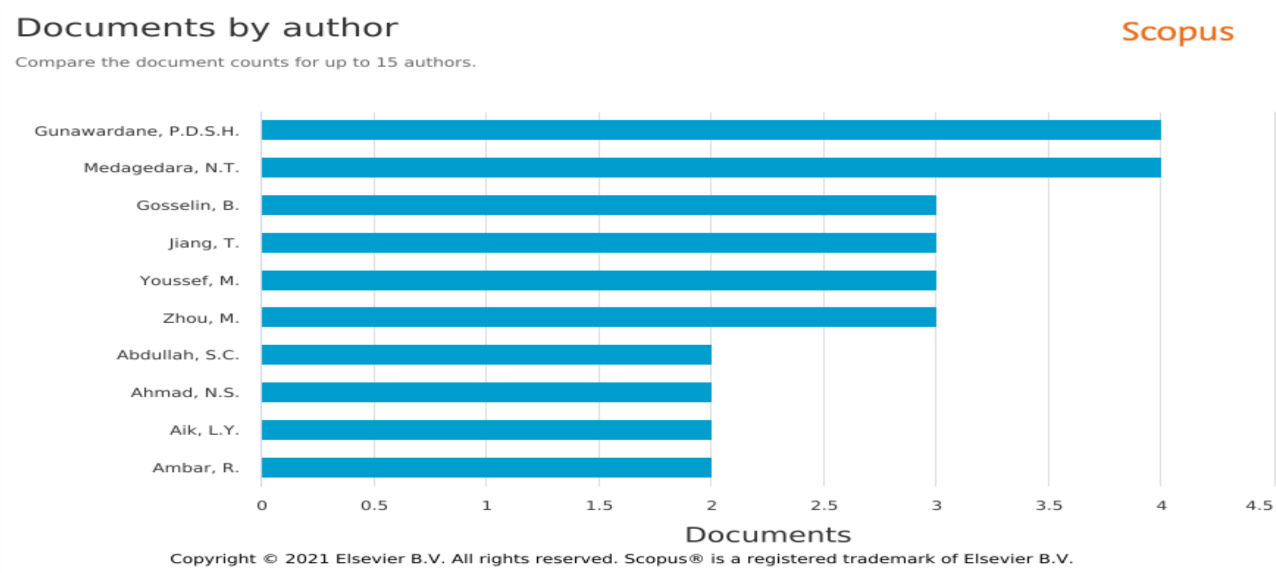

Figure 4: Documents by author.

Figure 4 shows the data of top authors whose documents were published related to gesture-controlled robot using flex sensors and RF transmission. Gunawardane, P.D.S.H. and Madagedara, N.T. have published total 4 documents each in this research domain followed by Gosselin, B., Jiang, T., and others

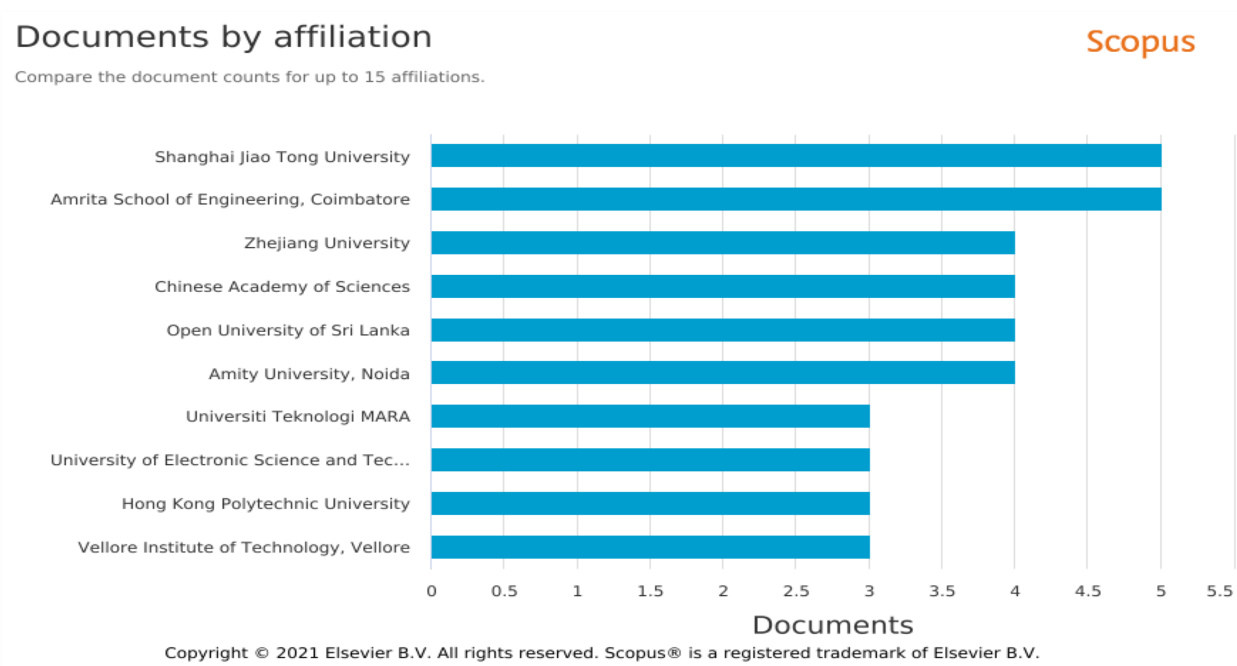

Figure 5: Documents by affiliation.

Figure 5 shows the data of documents affiliated with different sources. The research in this domain has been carried out more at Shanghai Jiao Tong University and Amrita School of Engineering, Coimbatore with 5 publications each, followed by Zhejiang University, Chinese Academy of Sciences, and others.

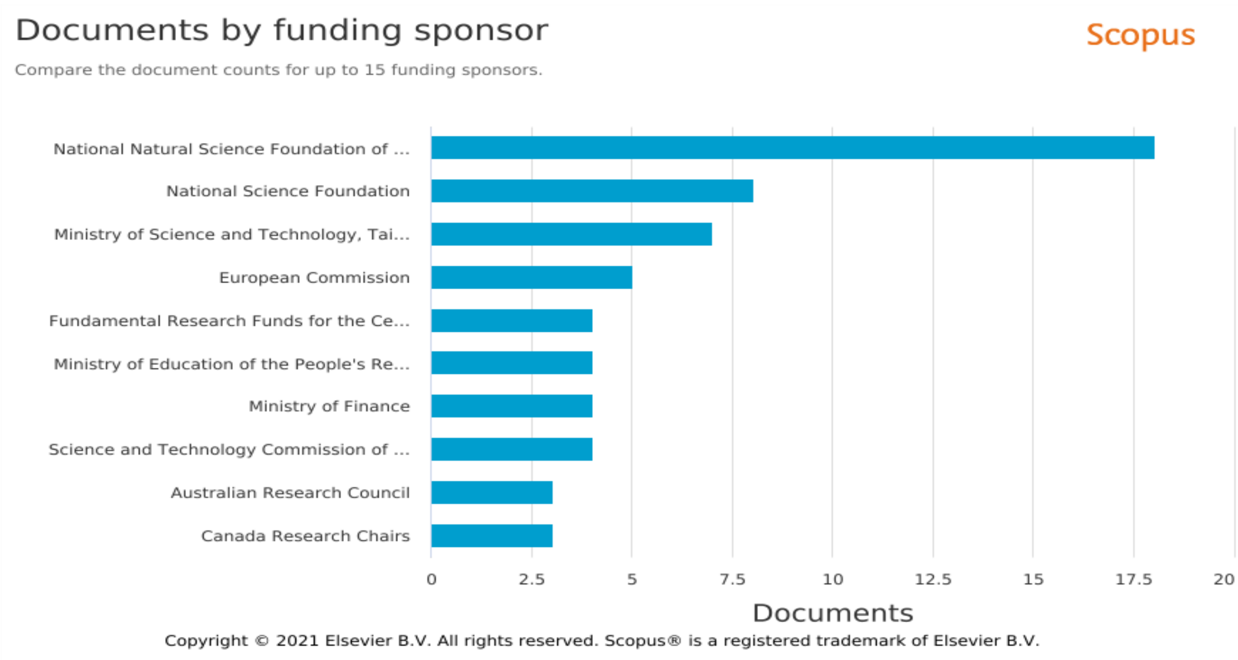

Figure 6: Documents by funding sponsor.

Figure 6 shows the data of the top 10 finding agencies that sponsored the research in this domain. National Natural Science Foundation of China is amongst the top funding agencies with more than 17 publications followed by National Science foundation, Ministry of Science and Technology, Taiwan, European Commission, and others. Figure 7 shows the data for percentage of documents belonging to different types. More than 50 % documents were conference papers, followed by 31.4% articles, 0.3% reviews,9.2% Conference reviews,1.4% Book chapters and 0.3% short surveys. Figure 8 shows the data for percentage of documents belonging to different subject areas. Most (31.2%) of the documents belong to Computer Science, 30% belong to engineering and so on.

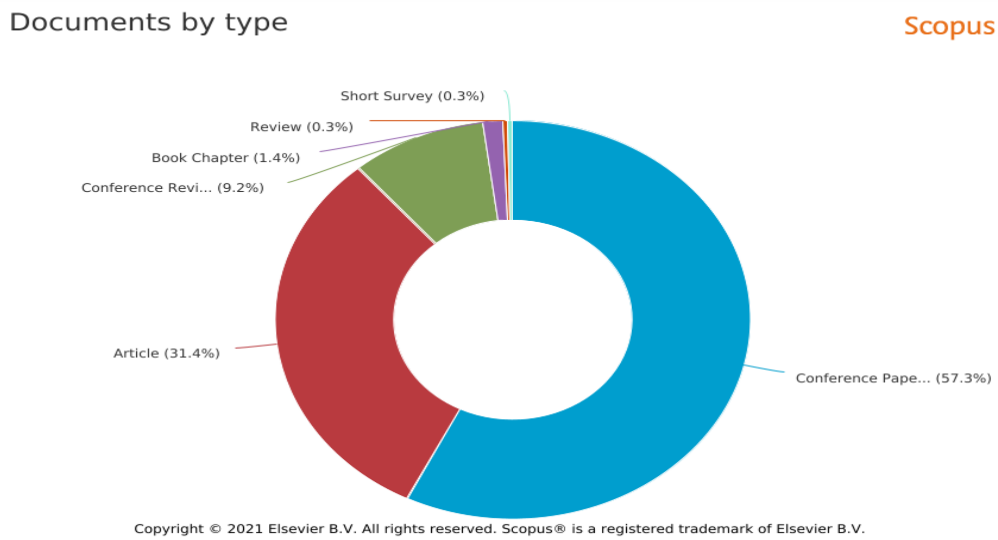

Figure 7: Percentage documents by type.

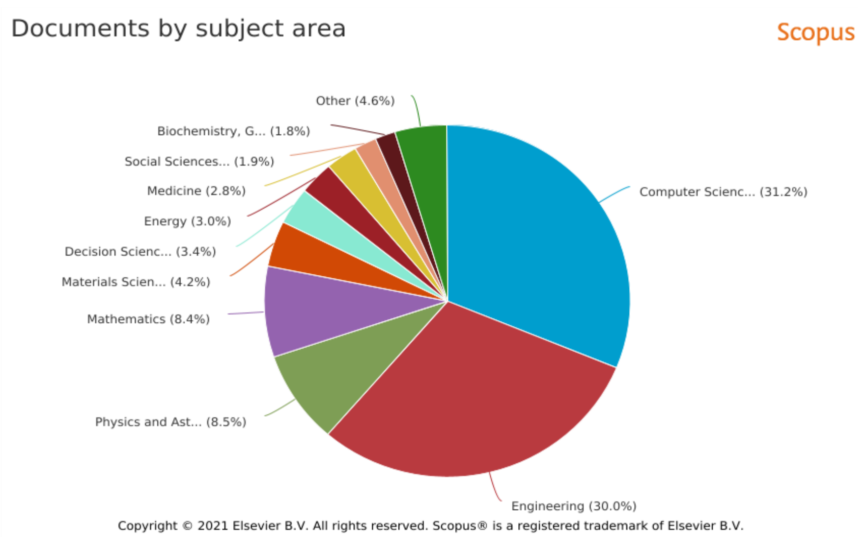

Figure 8: Documents by subject area

3. Bibliometric Analysis:

The field of bibliometrics analyses publications through statistical methods. It uses citation data to provide insight into the impact of research outputs. Bibliometrics can be used in combination with qualitative indicators such as peer review, funding received, and the number of patents and awards granted (Wagle & Harikrishnan, 2021).

3.1 Geographical Data Analysis:

Figure 9: Geographical distribution of the study related to gesture-controlled robot using flex sensors and RF transmission.

The geographical distribution of the study related to this domain is shown in Figure 9. The maximum number of publications are from Europe and Indian Subcontinent. The map above has been generated using GPS visualizer tool using the citation report fetched from Scopus database.

3.2 Network Analysis

The network visualization has been done using visualization tools of Gephi, VOS viewer, ScienceScape, and WordCloud.

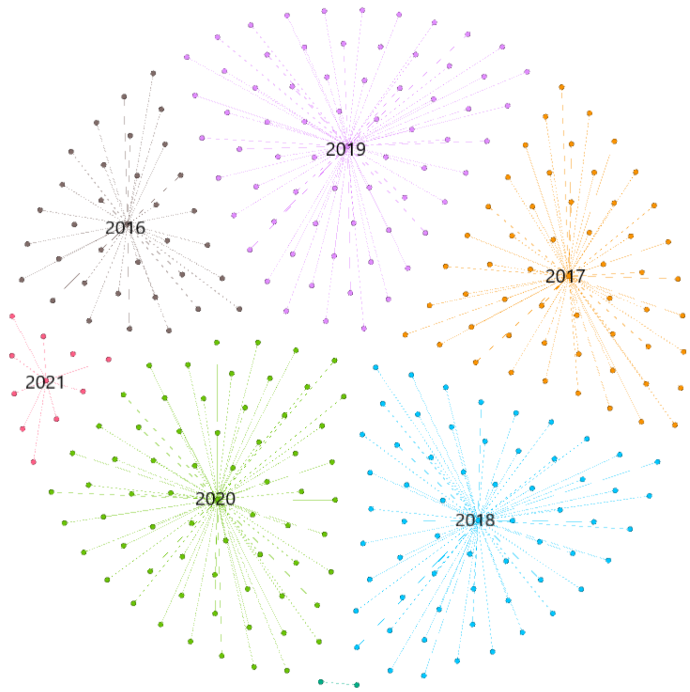

Figure 10: Cluster for Documents published per year related to gesture-controlled robot using flex sensors and RF transmission.

Figure 10 shows the cluster of publications per year from 2016 to 2021.The maximum publications of 241 are published in 2020 followed by 224 publications in 2019. Figure 11 shows the cluster of keywords co-occurring in the same documents. “gesture recognition”,” hand-gesture recognition”, “hand gesture” are some of the most prominent keywords and co-occur in multiple documents. Figure 12 shows the network of countries who co-authored publications.

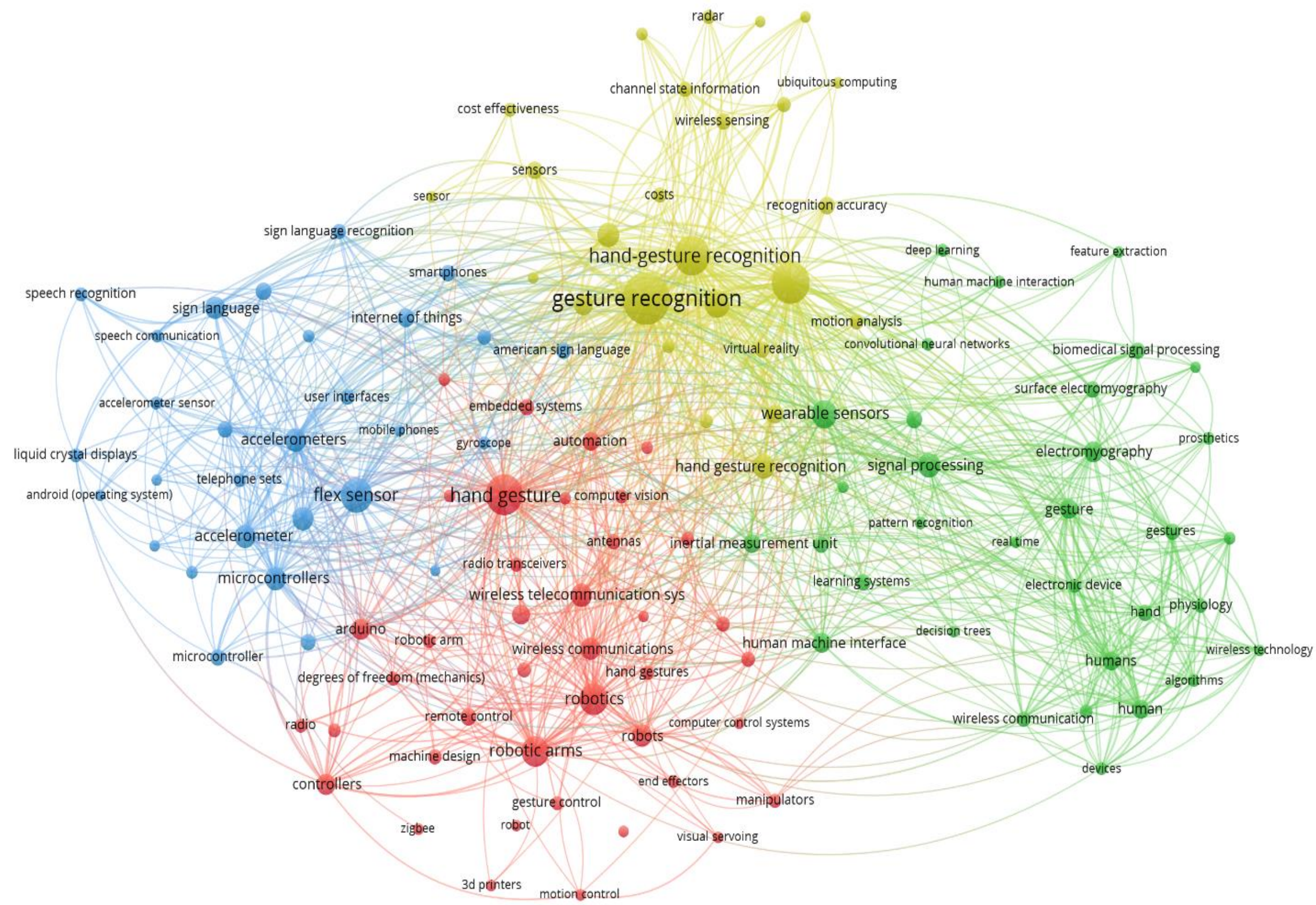

Figure 11: Co-occurrence of keywords

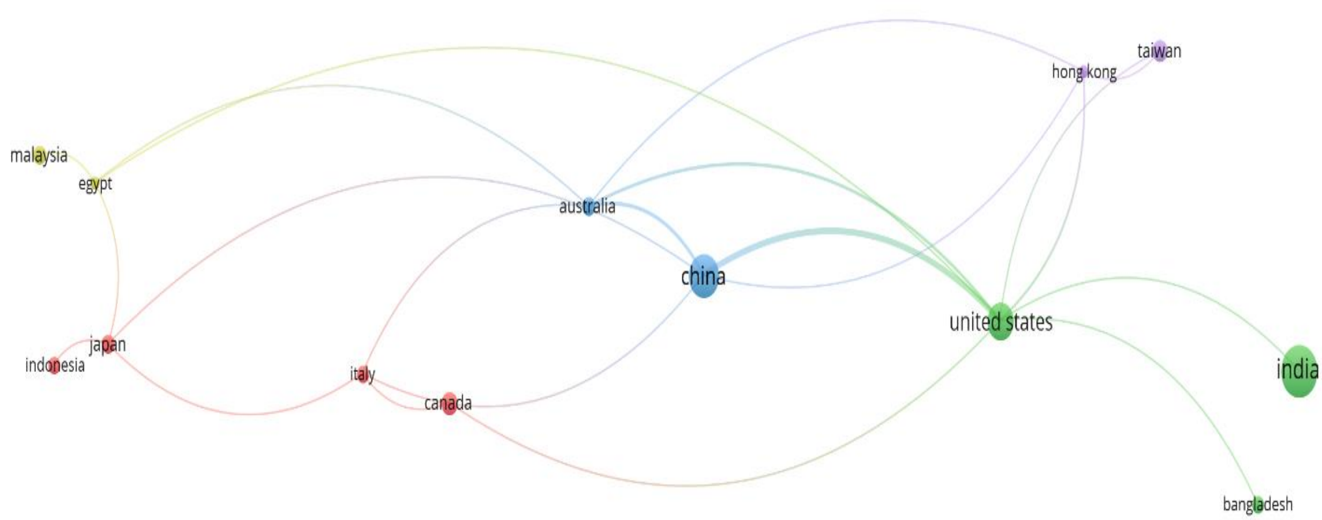

Figure 12: Co-Authorship of Countries

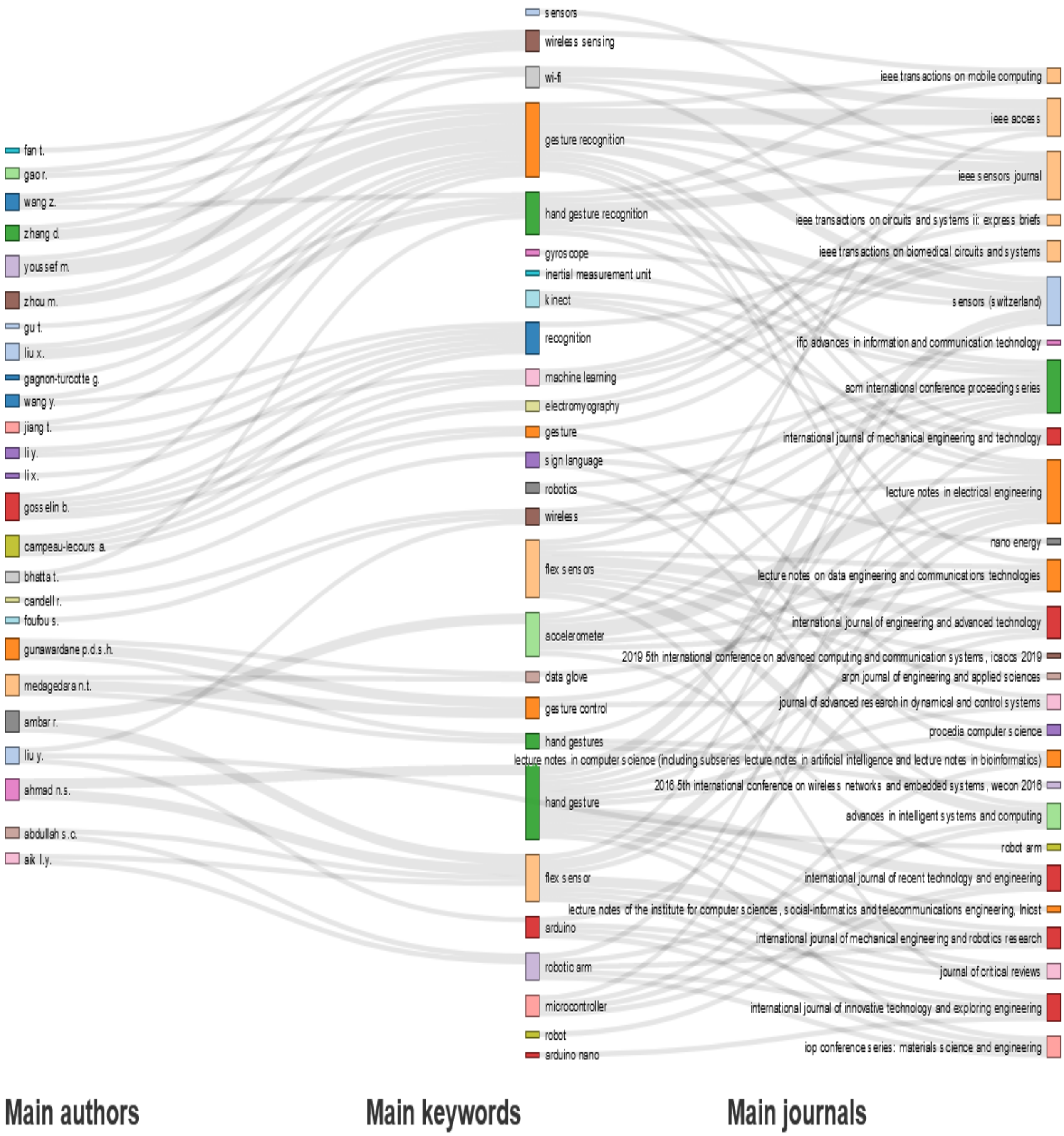

Figure 13: AKJ Sankey Graph: Main authors, Main Keywords, Main Journals.

Figure 13 is a AKJ Sankey Graph generated using ScienceScape, a data analysis tool for scientific literature. It displays the main authors, main keywords and main journals published the network formed talks about the keywords used by authors and the keywords occurred in the journals.

2016

- **accelerometer** 4 papers
- **hand gesture recognition** 3 papers
- **flex sensor** 2 papers
- **hand gesture** 2 papers
- **flex sensors** 2 papers
- **arduino** 2 papers
- **wireless** 2 papers
- **robotics** 2 papers
- **sensor** 2 papers
- **sign language recognition** 2 papers

2017

- **gesture recognition** 7 papers
- **hand gesture recognition** 5 papers
- **flex sensors** 3 papers
- **surface electromyography** 3 papers
- **hand gesture** 2 papers
- **bluetooth** 2 papers
- **gesture control** 2 papers
- **hand gestures** 2 papers
- **wi-fi** 2 papers
- **remote control** 2 papers

2018

- **gesture recognition** 9 papers
- **flex sensors** 7 papers
- **accelerometer** 5 papers
- **microcontroller** 5 papers
- **flex sensor** 4 papers
- **arduino** 3 papers
- **robot** 3 papers
- **hand gesture** 2 papers
- **hand gesture recognition** 2 papers
- **sign language** 2 papers

2019

- **gesture recognition** 12 papers
- **hand gesture** 10 papers
- **flex sensor** 8 papers
- **accelerometer** 8 papers
- **flex sensors** 7 papers
- **arduino** 5 papers
- **hand gesture recognition** 3 papers
- **gyroscope** 3 papers
- **microcontroller** 2 papers
- **sign language** 2 papers

2020

- **flex sensor** 11 papers
- **gesture recognition** 8 papers
- **hand gesture** 7 papers
- **arduino** 6 papers
- **hand gesture recognition** 4 papers
- **gesture** 3 papers
- **gesture control** 3 papers
- **data glove** 3 papers
- **accelerometer** 2 papers
- **sign language** 2 papers

2021

- **hand gesture recognition** 4 papers
- **gesture recognition** 2 papers
- **wireless sensing** 2 papers
- **radar** 2 papers
- **hand gesture** 1 paper
- **electromyography** 1 paper
- **sensors** 1 paper
- **wearable device** 1 paper
- **feature fusion** 1 paper
- **human computer interaction** 1 paper

Figure 14: Top keywords per year

Figure 14 shows the keywords most used in publications per year.” gesture recognition” has been the most prominent keyword for three years viz 2017 ,2018 and 2019, followed by ‘flex sensors’ in 2020. Figure 15 is just the tabular format of the AKJ Sankey graph shown earlier. It shows the main authors, main keywords and the main Journals published. Figure 16 shows the top journals published per year.

Main authors

- [no author name available] (27 papers)
- wang z. (6 papers)
- liu x. (5 papers)
- liu y. (5 papers)
- gunawardane p.d.s.h. (4 papers)
- medagedara n.t. (4 papers)
- wang y. (4 papers)
- zhang d. (4 papers)
- gao r. (3 papers)
- gosselin b. (3 papers)
- jiang t. (3 papers)
- li x. (3 papers)
- li y. (3 papers)
- youssef m. (3 papers)
- zhou m. (3 papers)
- zhou z. (3 papers)
- abdullah s.c. (2 papers)
- ahmad n.s. (2 papers)
- aik l.y. (2 papers)
- ambar r. (2 papers)
- bhatta t. (2 papers)
- campeau-lecours a. (2 papers)
- candell r. (2 papers)
- chen j. (2 papers)
- chen y. (2 papers)
- chu t. (2 papers)
- fan t. (2 papers)
- foufou s. (2 papers)
- gagnon-turcotte g. (2 papers)
- gu t. (2 papers)

Main keywords

- gesture recognition (40 papers)
- flex sensor (26 papers)
- hand gesture (24 papers)
- hand gesture recognition (21 papers)
- accelerometer (20 papers)
- flex sensors (20 papers)
- arduino (16 papers)
- microcontroller (10 papers)
- sign language (8 papers)
- bluetooth (7 papers)
- gesture (7 papers)
- gesture control (7 papers)
- hand gestures (7 papers)
- robotic arm (7 papers)
- wireless (7 papers)
- wireless sensing (7 papers)
- data glove (6 papers)
- gyroscope (6 papers)
- machine learning (6 papers)
- robotics (6 papers)
- wi-fi (6 papers)
- robot (5 papers)
- sensor (5 papers)
- arduino nano (4 papers)
- electromyography (4 papers)
- inertial measurement unit (4 papers)
- kinect (4 papers)
- recognition (4 papers)
- robot arm (4 papers)
- sensors (4 papers)

Main journals

- lecture notes in electrical engineering (8 papers)
- sensors (switzerland) (8 papers)
- ieee access (7 papers)
- acm international conference proceeding series (6 papers)
- advances in intelligent systems and computing (6 papers)
- ieee sensors journal (4 papers)
- lecture notes in computer science (including subseries lecture notes in artificial intelligence and lecture notes in bioinformatics) (4 papers)
- lecture notes of the institute for computer sciences, social-informatics and telecommunications engineering, lnicst (4 papers)
- international journal of engineering and advanced technology (3 papers)
- international journal of innovative technology and exploring engineering (3 papers)
- international journal of mechanical engineering and robotics research (3 papers)
- iop conference series: materials science and engineering (3 papers)
- procedia computer science (3 papers)
- proceedings of the 2017 international conference on wireless communications, signal processing and networking, wispnet 2017 (3 papers)
- 2016 5th international conference on wireless networks and embedded systems, wecon 2016 (2 papers)
- 2017 ieee biomedical circuits and systems conference, biocas 2017 - proceedings (2 papers)
- 2019 5th international conference on advanced computing and communication systems, icaccs 2019 (2 papers)
- arpn journal of engineering and applied sciences (2 papers)
- biomedical engineering online (2 papers)
- communications in computer and information science (2 papers)
- ieee transactions on biomedical circuits and systems (2 papers)
- ieee transactions on circuits and systems ii: express briefs (2 papers)
- ieee transactions on mobile computing (2 papers)
- ifip advances in information and communication technology (2 papers)
- international journal of mechanical engineering and technology (2 papers)
- international journal of recent technology and engineering (2 papers)
- journal of advanced research in dynamical and control systems (2 papers)
- journal of critical reviews (2 papers)
- lecture notes on data engineering and communications technologies (2 papers)
- nano energy (2 papers)

Figure 15: Main authors, Main keywords, and Main Journals.

2016

- acm international conference proceeding series 2 papers
- proceedings of 2015 3rd international conference on image information processing, iciip 2015 2 papers
- lecture notes in electrical engineering 1 paper
- ieee access 1 paper
- advances in intelligent systems and computing 1 paper
- procedia computer science 1 paper
- biomedical engineering online 1 paper
- 12th ieee international conference electronics, energy, environment, communication, computer, control: (e3-c3), indicon 2015 1 paper
- 2015 ieee 12th international conference on electronic measurement and instruments, icemi 2015 1 paper
- 2015 ieee bombay section symposium: frontiers of technology: fuelling prosperity of planet and people, ibss 2015 1 paper

2017

- advances in intelligent systems and computing 2 papers
- 2016 5th international conference on wireless networks and embedded systems, wecon 2016 2 papers
- communications in computer and information science 2 papers
- proceedings - 2016 9th international congress on image and signal processing, biomedical engineering and informatics, cisp-bmei 2016 2 papers
- acm international conference proceeding series 1 paper
- lecture notes of the institute for computer sciences, social-informatics and telecommunications engineering, lnicst 1 paper
- iop conference series: materials science and engineering 1 paper
- arpn journal of engineering and applied sciences 1 paper
- biomedical engineering online 1 paper
- ieee transactions on circuits and systems ii: express briefs 1 paper

2018

- proceedings of the 2017 international conference on wireless communications, signal processing and networking, wispnet 2017 3 papers
- sensors (switzerland) 2 papers
- lecture notes in computer science (including subseries lecture notes in artificial intelligence and lecture notes in bioinformatics) 2 papers
- 2017 ieee biomedical circuits and systems conference, biocas 2017 - proceedings 2 papers
- lecture notes in electrical engineering 1 paper
- ieee access 1 paper
- acm international conference proceeding series 1 paper
- ieee sensors journal 1 paper
- lecture notes of the institute for computer sciences, social-informatics and telecommunications engineering, lnicst 1 paper
- arpn journal of engineering and applied sciences 1 paper

2019

- sensors (switzerland) 5 papers
- lecture notes in electrical engineering 3 papers
- international journal of engineering and advanced technology 3 papers
- international journal of innovative technology and exploring engineering 3 papers
- ieee access 2 papers
- advances in intelligent systems and computing 2 papers
- lecture notes of the institute for computer sciences, social-informatics and telecommunications engineering, lnicst 2 papers
- procedia computer science 2 papers
- 2019 5th international conference on advanced computing and communication systems, icaccs 2019 2 papers
- proceedings of ieee sensors 2 papers

2020

- lecture notes in electrical engineering 3 papers
- international journal of mechanical engineering and robotics research 3 papers
- ieee access 2 papers
- acm international conference proceeding series 2 papers
- journal of advanced research in dynamical and control systems 2 papers
- journal of critical reviews 2 papers
- lecture notes on data engineering and communications technologies 2 papers
- nano energy 2 papers
- lecture notes in computer science (including subseries lecture notes in artificial intelligence and lecture notes in bioinformatics) 1 paper
- iop conference series: materials science and engineering 1 paper

2021

- ieee sensors journal 2 papers
- sensors (switzerland) 1 paper
- ieee access 1 paper
- advances in intelligent systems and computing 1 paper
- asia-pacific microwave conference proceedings, apmc 1 paper
- ieee systems journal 1 paper
- ieee transactions on human-machine systems 1 paper
- ieee transactions on power electronics 1 paper
- journal of robotics 1 paper

Figure 16: Top Journals per year.

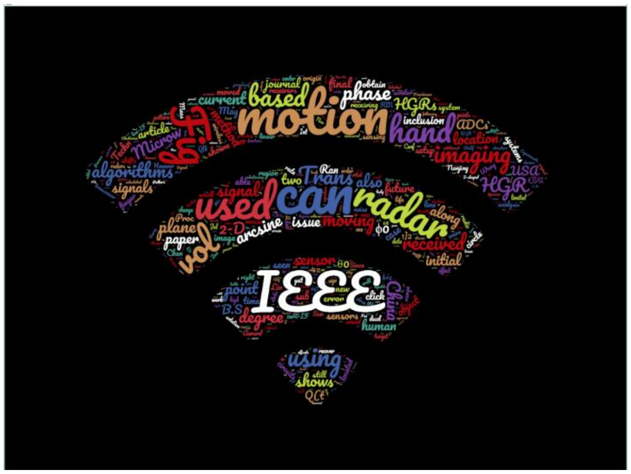

Figure 17: Word Cloud.

Figure 17 shows the word cloud generated using online WordCloud tool for one of the topmost cited documents published. The words IEEE, radar, and motion are the most used words in this document.

3.3 Statistical Analysis of publication citation

Table 5: No. of citations per year and total citations (Scopus Database).

Year	2016	2017	2018	2019	2020	2021	Total
Number of Citations	6	54	184	297	462	165	1165

Table 5 shows the number of citations per year in Scopus Database. Since 2016 the number citations started gradually increasing and in 2020 maximum documents were cited. There are total 165 citations in 2021 till now, also the total citations for 293 documents is 1165 for Scopus database. 'Rapid Fabrication of Soft, Multilayered Electronics for Wearable Biomonitoring' is the most cited paper for Scopus database with 72 citations.

Table 6: Citation Analysis of Top 10 publications related to gesture-controlled robot using flex sensors and RF transmission.

Sr No	Publication Year	Document Title	<2016	2016	2017	2018	2019	2020	2021	Total
1	2016	"Rapid Fabrication of Soft, Multilayered Electronics for Wearable Biomonitoring"	0	0	9	22	17	20	4	72
2	2016	"Volume-invariant ionic liquid microbands as highly durable wearable biomedical sensors"	0	4	10	15	20	14	9	72
3	2017	"Highly Sensitive Textile Strain Sensors and Wireless User-Interface Devices Using All-	0	0	2	11	16	28	5	62

		Polymeric Conducting Fibers”								
4	2016	“Wireless Hand Gesture Recognition Based on Continuous-Wave Doppler Radar Sensors”	0	0	4	20	15	16	3	58
5	2020	“Sign-to-speech translation using machine-learning-assisted stretchable sensor arrays”	0	0	0	0	0	16	29	45
6	2016	“Hybrid Control of a Vision-Guided Robot Arm by EOG, EMG, EEG Biosignals and Head Movement Acquired via a Consumer-Grade Wearable Device”	0	0	5	4	14	16	1	40
7	2017	“Evaluation of the Myo armband for the classification of hand motions”	0	0	0	8	11	14	4	37
8	2017	“Proximity based IoT device authentication”	0	0	0	7	7	15	3	32
9	2018	“WiCatch: A Wi-Fi Based Hand Gesture Recognition System”	0	0	0	0	9	16	3	28
10	2019	“A Ubiquitous WiFi-Based Fine-Grained Gesture Recognition System”	0	0	0	0	1	17	6	24

Conclusion

From our survey we have seen that hand gesture recognition is an emerging field of study with a huge scope and wide variety of applications. The main principle of hand gesture-controlled systems are the gesture recognition architecture and the components used for implementation.

Sensors play a major role in gesture recognition process by generating signals for every gesture performed by user. Most of the documents published in this research domain are from Europe and Indian Subcontinent. Maximum documents belong to Computer science followed by Engineering. National Natural Science Foundation of China has conducted maximum study in this field with total 18 publications. Maximum documents have been published in 2019 with 69 publications. The top most cited documents belong to 'Advanced Functional Materials' and 'Materials Horizons' with 72 citations each.

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