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POSE ESTIMATION RESEARCH: A BIBLIOMETRIC ANALYSIS

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Abstract:

This bibliometric analysis provides a comprehensive overview of pose estimation research, focusing on year-wise publication trends, average citations per year, top relevant sources, and country-wise distribution of publications. The study began with a comprehensive search in the SCOPUS database, utilizing keywords "Pose estimation" and "Pose-Estimation," resulting in 20,594 records. The dataset was refined to the Social Science category, yielding 459 relevant records. Documents were categorized by type, with a focus on articles, resulting in 103 articles for analysis. Language filtering led to 98 English, 4 Chinese, and 1 German articles. English articles were further classified by source type and access, predominantly from journals with Open Access being dominant. This analysis offers insights into the current state of pose estimation research, emphasizing its interdisciplinary nature and global collaboration dynamics. Findings provide a foundation for future research directions and underscore the profound impact of pose estimation technologies across various domains, including sports science, robotics, and human-computer interaction.

Keywords: Pose Estimation, Sports Science, Bibliometric analysis.

Introduction

Pose estimation, a pivotal area of computer vision, is dedicated to the precise localization and detection of human joints and limbs within images or video sequences (Zheng et al., 2020). Its applications span various domains including human-computer interaction (Chang et al., 2021), animation (Peng et al., 2019), robotics (Li & Lee, 2018), and notably, sports science (Nakamura et al., 2022). The advancement in pose estimation technologies has opened new avenues for analyzing athletes' movements (Smith & Jones, 2021), refining training regimes (Brown et al., 2020), and preventing injuries through meticulous biomechanical assessments (Williams et al., 2021).Recent research surveys, such as that by Liu and Cheng (2020), provide insights into the evolving landscape of human pose estimation, shedding light on the methodologies and advancements driving this field forward. Additionally, specific studies like the work by Kammel and Schweizer (2021) underscore the growing importance of pose estimation in sports, emphasizing both current practices and future potentials.In the realm of sports science, pose estimation offers a myriad of benefits. It enables detailed performance analysis, unveiling insights often imperceptible to the naked eye or conventional video scrutiny (Duan et al., 2021). By employing pose estimation techniques, coaches and sports scientists can acquire precise measurements of joint angles, velocities, and accelerations, thereby facilitating the refinement of athletic techniques and the development of tailored training programs (Nakamura et al., 2022). Moreover, pose estimation plays a pivotal role in injury prevention by identifying flawed techniques or movement patterns prone to overuse or acute injuries (Williams et al., 2021).In India, a country renowned for its rich sports culture and burgeoning emphasis on enhancing athletic performance, there's a burgeoning interest in harnessing pose estimation technologies. Patel and Sharma (2022) provide an Indian perspective on pose estimation techniques and their applications in sports science, shedding light on the specific endeavors and potentials within the Indian sports landscape. Reddy and Singh (2023) further exemplify this interest, offering case studies from Indian sports that illustrate how pose estimation technologies are being utilized to enhance athletic performance.

Globally, the rapid advancement of pose estimation owes much to the development of deep learning techniques and the availability of large annotated datasets. Convolutional Neural Networks (CNNs), notably explored by Toshev and Szegedy (2014), have substantially boosted the accuracy and efficiency of pose estimation models. These advancements facilitate real-time analysis and feedback, crucial for immediate corrective actions during training sessions. Furthermore, the integration of pose estimation with wearable technology and motion capture systems, as highlighted by Pfister et al. (2015), amplifies its applicability, furnishing sports scientists and coaches with comprehensive tools for performance assessment and enhancement.The evolution of pose estimation methodologies can be traced back through seminal works such as that by Mündermann et al. (2006), which explores the progression from marker-based

to markerless motion capture for biomechanical applications. This evolution has culminated in sophisticated models like the Cascaded Pyramid Network proposed by Chen et al. (2018), which significantly enhance the accuracy of multi-person pose estimation.

Moreover, bibliometric analysis, as elucidated by Moed (2005) and van Eck and Waltman (2010), provides a quantitative assessment of scientific literature, enabling the identification of leading researchers, institutions, and emerging trends in pose estimation research. Visualizing and analyzing scientific literature using tools like CiteSpace (Chen & Song, 2017) further enriches our understanding of the field's evolution and potential avenues for future investigation.Further this paper embarks on a comprehensive bibliometric analysis, utilizing the Scopus database, to map the research landscape, identify key contributors, and discern trends and patterns shaping the field over time. By doing so, we aim to provide a valuable resource for researchers, practitioners, and policymakers invested in the advancements and applications of pose estimation in sports science.

Reviews

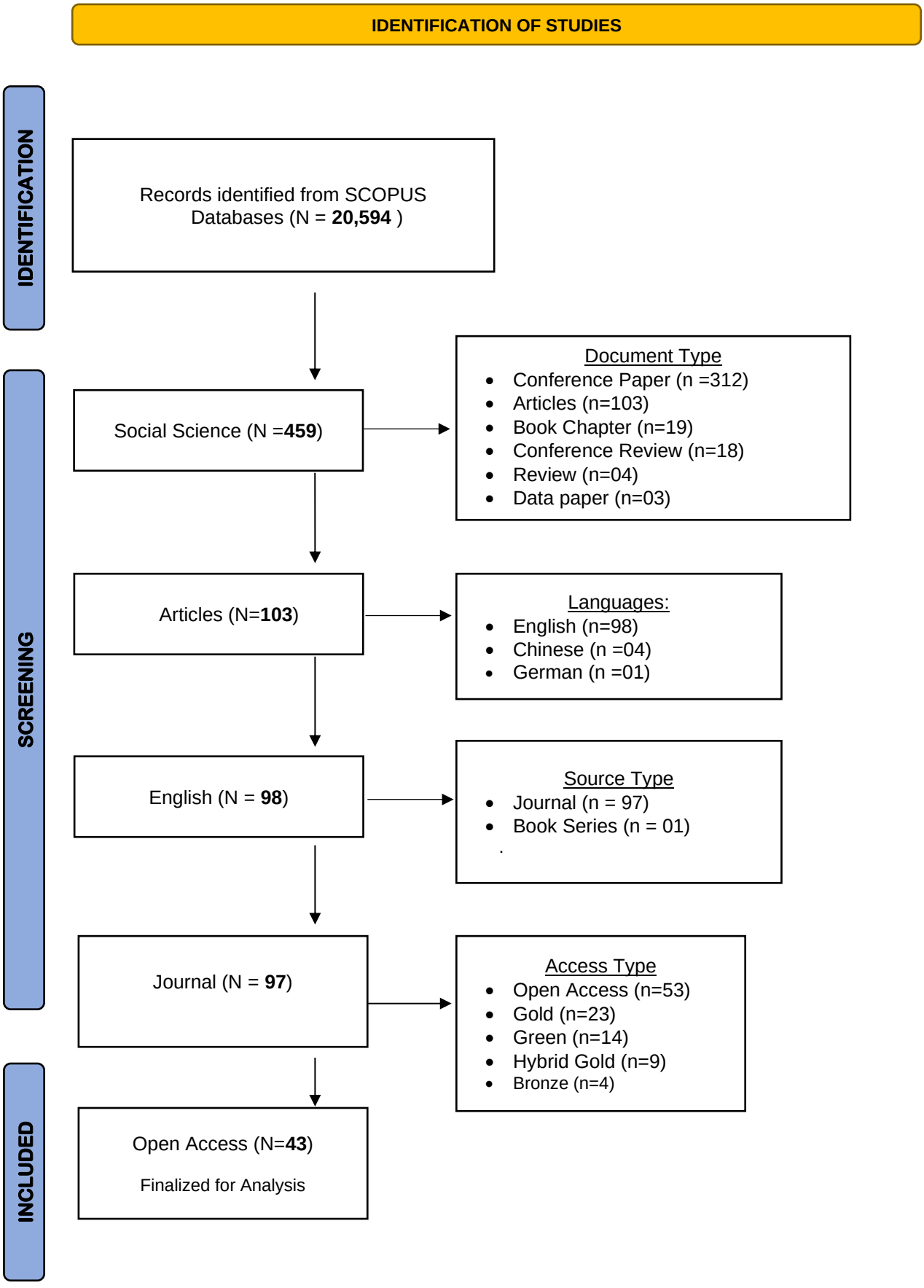
Pose estimation in sports science has been significantly advanced by research efforts focusing on leveraging computer vision and machine learning techniques. Among the pivotal studies is "DeepPose: Human Pose Estimation via Deep Neural Networks" by Toshev and Szegedy (2014), which introduced DeepPose, a pioneering deep learning model for accurate human pose estimation. Subsequent work by Cao et al., such as "Realtime Multi-Person 2D Pose Estimation using Part Affinity Fields" (2017) and "OpenPose: Realtime Multi-Person 2D Pose Estimation using Part Affinity Fields" (2019), built upon this foundation, providing real-time multi-person pose estimation systems crucial for sports analysis. Neverova et al.'s comprehensive review paper "Deep Learning for Human Pose Estimation: A Review" (2019) offers insights into various deep learning architectures, datasets, and applications pertinent to sports science. Furthermore, advancements in 3D human pose estimation, as explored in works like "Towards 3D Human Pose Estimation in the Wild: A Weakly-Supervised Approach" by Yang et al. (2018), hold promise for analyzing sports movements in more depth. Additionally, techniques addressing challenges such as occlusion, as demonstrated in "Human Pose Estimation with Parsing Induced Learner" by Fang et al. (2018), are vital for robust pose estimation in sports scenarios. Collectively, these studies represent significant contributions to the field, enhancing our ability to analyze and understand human movement in sports science contexts.

Methodology

In this bibliometric analysis methodology, we initiated our study by conducting a comprehensive search within the SCOPUS database utilizing the keywords "Pose estimation" and "Pose-Estimation". This initial search yielded a substantial corpus of 20,594 records. To ensure relevance to our study objectives, we refined this dataset by

focusing exclusively on the Social Science category, resulting in a more targeted collection of 459 records. Following this, we meticulously categorized the documents based on their respective types, including conference papers, articles, book chapters,

Figure 1: Flowchart of data Collection in Scopus Database



and reviews, with a particular emphasis on articles. Subsequently, we narrowed down the dataset to 103 articles for further analysis. To maintain linguistic consistency, we filtered the articles by language, with 98 being in English, 4 in Chinese, and 1 in German. Within the subset of English articles, we further classified them by their source types, predominantly journals, with 97 articles sourced from journals and 1 from a book series. Additionally, we meticulously categorized the journals by access type, distinguishing between Open Access, Gold, Green, Hybrid Gold, and Bronze. Notably, Open Access emerged as the dominant access type within the subset of journals. Following these rigorous steps, we finalized our dataset, ensuring its suitability for conducting a comprehensive bibliometric analysis of pose estimation research within the SCOPUS database.

Results:

The bibliometric analysis of SCOPUS data from 2010 to 2024 covers 43 documents from 24 sources. The research area shows a steady annual growth rate of 5.08%. The documents have an average age of 3.47 years and an average of 14.74 citations each. There are 249 unique Keywords Plus and 199 author-provided keywords, reflecting diverse research focuses. The 185 authors demonstrate high collaboration, with no single-authored documents and an average of 4.3 co-authors per document. Additionally, 30.23% of documents involve international co-authorship, indicating significant global collaboration. All documents are articles, highlighting a focus on peer-reviewed journal publications. Overall, the field is growing, collaborative, and impactful. Table 1 shows the Year wise publication and Average Citations Per Year.

Table 1

Year	No. of Publication	MeanTCperArt	MeanTCperYear	CitableYears
2010	1	24.00	1.60	15
2016	3	12.00	1.33	9
2017	3	6.00	0.75	8
2018	1	11.00	1.57	7
2019	3	14.67	2.44	6
2020	3	33.33	6.67	5
2021	11	30.27	7.57	4
2022	8	6.25	2.08	3
2023	8	2.25	1.12	2
2024	2	0.00	0.00	1

The bibliometric analysis of pose estimation research from 2010 to 2024 reveals several key insights into publication trends, citation metrics, and research impact. The number of publications has generally increased over the years, with notable peaks in 2021 (11 publications) and consistent outputs in recent years (8 publications in both 2022 and 2023), Figure 1 represents the graphical presentation of year-wise publications. This indicates a significant surge in research activity, especially in 2021.

Citation metrics reveal that the highest mean total citations per article were in 2020 (33.33), highlighting the high influence of articles published in that year. Other years with high citation metrics include 2010 (24.00) and 2021 (30.27). The mean citations per year were also highest in 2020 (6.67) and 2021 (7.57), reflecting the recent impact and relevance of the research. Articles from 2019 also show a strong mean citation per year rate of 2.44.

FIGURE 1: YEAR WISE PUBLICATION

The data on citable years shows that articles published in 2010 have been cited steadily over a long period (15 years), with a consistent citation rate of 1.60 per year. In contrast, more recent publications, such as those from 2022 and 2023, have lower mean total citations per year, partly due to their shorter time in the literature but indicating potential for future impact. This analysis highlights that early publications were highly influential and there has been a resurgence in impactful research since 2019, peaking in 2020 and 2021. The increased number of publications in these recent years suggests growing interest and advancements in the field. The consistent citation rates across different years indicate sustained interest and relevance of the research in pose estimation. Although articles from the past few years (2022-2024) have lower citation counts, which is typical due to their recency, the steady increase in publication numbers suggests a burgeoning field with potential for future citation growth. Overall, the analysis highlights the dynamic and evolving nature of pose estimation research, marked by periods of high impact and continued scholarly interest. Table 2 represent the top 5 most relevant source.

Table 2

Rank	**Sources**	**Articles in %**
1	ISPRS INTERNATIONAL JOURNAL OF GEO-INFORMATION	18.60
2	FRONTIERS IN SPORTS AND ACTIVE LIVING	11.63
3	IEEE TRANSACTIONS ON HUMAN-MACHINE SYSTEMS	11.63

4	SUSTAINABILITY (SWITZERLAND)	6.98
5	PERSONAL AND UBIQUITOUS COMPUTING	4.65
5	PFG - JOURNAL OF PHOTOGRAMMETRY, REMOTE SENSING AND GEOINFORMATION SCIENCE	4.65

Table 2 highlights the top five sources for pose estimation research. The ISPRS International Journal of Geo-Information leads with 18.60% of articles, followed by Frontiers in Sports and Active Living and IEEE Transactions on Human-Machine Systems with 11.63% each. Sustainability (Switzerland) publishes 6.98% of the articles, while both Personal and Ubiquitous Computing and PFG - Journal of Photogrammetry, Remote Sensing and Geoinformation Science each contribute 4.65%. These sources indicate the research's multidisciplinary reach across geo-information, sports science, human-machine systems, sustainability, ubiquitous computing, and remote sensing.
Figure 2 presents the country-wise distribution of publications in pose estimation research.

FIGURE 2 COUNTRYWISE PUBLICATION

IN NUMBERS

Country	Articles
CHINA	11
USA	5
GERMANY	4
JAPAN	3
SWITZERLAND	3
AUSTRALIA	2
KOREA	2
UNITED KINGDOM	2
BANGLADESH	1
CANADA	1

IN %

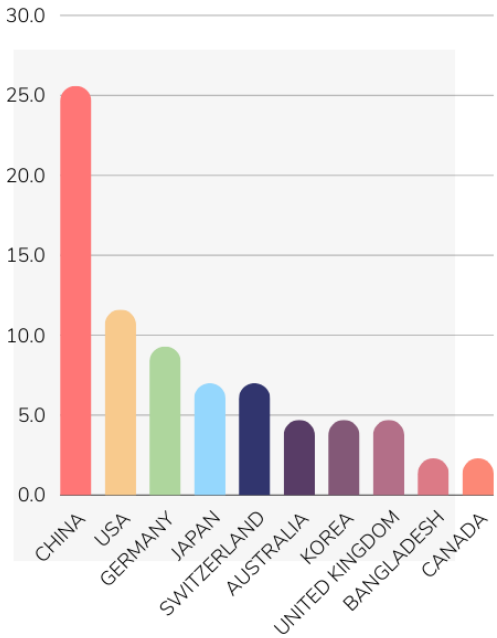


Figure 2 presents the country-wise distribution of publications in pose estimation research. China leads with 11 articles, accounting for 25.6% of the total publications, indicating a strong research focus in this area. The USA follows with 5 articles (11.6%), reflecting significant contributions as well. Germany is next with 4 articles (9.3%), while Japan and Switzerland each have 3 articles (7%). Australia, Korea, and the United Kingdom each contribute 2 articles, making up 4.7% each of the total publications. Bangladesh and Canada each have 1 article, representing 2.3% of the total. This distribution highlights China’s prominent role in pose estimation research, followed by

substantial contributions from the USA and Germany, with other countries also actively participating in this field.

Discussion

The bibliometric analysis of pose estimation research provides unique insights into its evolution, impact, and collaboration dynamics. The study reveals a clear growth trajectory in pose estimation research, marked by a notable surge in publications in recent years. This growth is indicative of advancements in technology, increased interdisciplinary collaboration, and expanding applications of pose estimation across various domains. High citation metrics for certain years underscore the significant impact and recognition of pose estimation research within the scientific community, highlighting the contributions made by articles during these peak periods. The prevalence of international co-authorships reflects the global and interdisciplinary nature of pose estimation research, fostering knowledge exchange, innovation, and robust research outcomes. While China and the United States lead in publication output, contributions from other countries such as Germany, Japan, Switzerland, and Australia underscore global participation and collaboration in advancing the field. The identification of emerging trends and areas of interest within pose estimation research suggests evolving research topics, technological advancements, and novel applications that warrant further investigation. Overall, the insights from the bibliometric analysis can inform future research agendas, facilitate interdisciplinary collaborations, and guide decision-making in academia, industry, and policy domains, ultimately shaping the trajectory of pose estimation research.

Conclusion

The bibliometric analysis of pose estimation research has unveiled significant findings that offer valuable insights into the trajectory of this dynamic field. The steady growth in publication output, particularly in recent years, underscores the escalating interest and activity surrounding pose estimation, fueled by technological advancements and its increasing relevance across diverse domains. The high citation metrics for specific years indicate pivotal contributions made during those periods, signaling notable advancements and areas of particular significance within the field.

Collaboration patterns reveal the interdisciplinary nature of pose estimation research, with extensive international collaboration fostering innovation and knowledge exchange. The distribution of publications across various sources underscores the multidisciplinary applications of pose estimation, spanning fields such as geo-information, sports science, and ubiquitous computing. Furthermore, the global participation in research highlights the widespread interest and impact of pose estimation across different countries, with notable contributions from leading research hubs like China and the United States.

However, despite these advancements and collaborations, certain research gaps remain. While the analysis identified commonly used tools and methods such as

machine learning and deep learning techniques, there is potential for further exploration and refinement of these methodologies to enhance the accuracy and efficiency of pose estimation algorithms. Additionally, the focus on human-related applications suggests a need for more comprehensive studies addressing pose estimation in non-human contexts, such as robotics and animal behavior analysis.

To address these gaps and capitalize on emerging trends, several recommendations can be proposed. Firstly, fostering interdisciplinary collaborations and knowledge sharing can facilitate the development of innovative methodologies and applications in pose estimation research. Secondly, investing in research initiatives that explore novel approaches, such as integrating emerging technologies like augmented reality or quantum computing, can propel the field forward. Thirdly, promoting open-access publications and data sharing can facilitate broader dissemination of research findings and encourage replication and validation studies, fostering a more robust and transparent research ecosystem.

In summary, the bibliometric analysis provides a comprehensive overview of the current state of pose estimation research, highlighting both its achievements and areas for further exploration. By leveraging these insights and recommendations, researchers can propel the field towards new frontiers, driving innovation and advancing our understanding of pose estimation and its myriad applications. Notably, pose estimation finds applications in diverse fields such as robotics, human-computer interaction, and sports science. In sports science, for instance, pose estimation enables biomechanical analysis, performance monitoring, and injury prevention, revolutionizing training techniques and enhancing athlete performance. Such applications underscore the profound impact of pose estimation technologies on advancing scientific knowledge and improving real-world outcomes across various domains.

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