Choose a soft place and embark on a roadmap regarding soft robotics use in orthotics

Severino Netto
Faculty of Electrical Engineering
Federal University of Uberlândia
Uberlândia, Brazil
ORCID: 0000-0003-2889-570X

Bruno Spinelli
Edmond and Lily Safra International Institute of Neurosciences
Macaíba, Brazil
ORCID: 0000-0001-8302-7505

Aryel Medeiros
Laboratory of Technological Innovation in Health
Natal, Brazil
ORCID: 0000-0001-5784-152X

Alcimar Soares
Faculty of Electrical Engineering
Federal University of Uberlândia
Uberlândia, Brazil
ORCID: 0000-0003-1100-3533

***Abstract* — The technological revolution of the last decades allowed the development of new approaches to develop more effective orthotics. Soft robotics is a sub-field of robotics dealing with constructing robots from highly compliant materials, commonly bioinspired, similar to those found in living organisms. Soft Robotics aims to surpass some challenges faced by Hard Robotics like non collaboration strategies, complexity and manufacture cost, based on structural advantages many studies investigate the use of Soft Robotics principles in orthotics fabrication. These studies achieved significant results and suggested that soft robotics could accelerate more humanlike devices, promoting comfort, lightweight and better usability for the users. This study aims to develop quantitative bibliometric research, i.e., a roadmap, to evaluate the development of studies involving soft robotics and orthotics development. The results showed that soft robotics provides innovative solutions for orthotics development studies. Although, there were few publications related to these topics, it is clear that the scientific applications are growing fast, and are developing higher-usability devices based on the soft robotics principles.**

Keywords — Soft Robotics, Orthotics, Assistive Technologies, Soft Orthotics.

I. INTRODUCTION

In the past few years, studies have shown that the importance of assistive devices in various motor rehabilitation processes, as far as biomedical engineering is concerned, a sub-area of great importance can be evidenced, which is assistive technology. At this point, many advances have been made in the development of orthotics in several areas like manufacturing materials, control strategies and usability (SHURR, 2002).

However, some of the solutions never cross the barrier between scientific development and access to users in a commercial way (HOEKSTRA, 2019). The explanation for this fact is very broad, in addition to the technical aspects, there are regulatory aspects for each region, pricing and the development of business models in general.

Even so, the objective of this work is more restricted, we will evaluate the development of orthoses based on soft robotics with a bibliometric methodology, although soft robotics refers a lot to actuators and movement, we also evaluate soft principles in passive and active orthoses. Evaluating the state of the art in this area and its evolution in recent years is important to form the big picture, analyzing development centers, topics studied and new applied technologies.

A. *Orthotics*

Orthoses are defined by externally applied device used to modify the structural or functional characteristics of the neuromusculoskeletal system. Individuals who are in a condition of motor impairment, whether due to diseases, accidents or other causes, can use orthoses to enhance the rehabilitation process or restore motor function through the continuous use of the device.

However, the development of such devices is not trivial, there are many variables to be considered for the patient to develop high adherence to use, as follows:

- Comfort;
- Durability;
- Usability;
- Effectiveness;
- Weight.

PEACO and collaborators (2011) also mention other important characteristics in the development of orthotics, but only those that can be achieved through the use of soft robotics strategies will be addressed.

B. *Soft Robotics*

Soft robotics enables the development of innovative biomedical technologies, because the compliance and mechanical properties of soft robots make them especially interesting for medical applications, especially motor assistive devices.

Based on the characteristics addressed in the past topic, soft robotics materials and strategies can surpass these difficulties. On example, many studies used soft materials for reduce weight and increase comfort in wearable devices. The exchange of hard joints to soft joints and actuators can perform more natural movements, allowing tasks that cannot be performed masterfully.

In conjunction with refined control strategies, these features tend to improve the device's usability and effectiveness on a day-to-day basis. Finally, the use of soft materials can promote more comfort to the patient, having devices that better fit the anatomy of each patient, such adaptation reduces the wear of action, increasing the durability of the orthosis

II. OBJECTIVES

Evaluate the development of orthoses based on soft robotics with a bibliometric methodology.

III. METHODOLOGY

A. Justification

Science and technology roadmaps can be a tool to evaluate the technological and scientific development in a specific area (DE SOUZA, 2018). They are widely used in academic research and industry to portray the relationships between technology, science and their applications. Roadmaps help to definethe development level of an application or technology and their probability of growth in different fields.

They are employed as decision aids to improve the arrangement of resources and activities in progressively uncertain and complex areas (KOSTOFF, 2001). Therefore, results obtained by roadmaps analyses help to identify potential areas to research and invest. Despite, geographic analysis can be very useful for research groups in the area that seek partnerships or networking in the development of new approaches in assistive technology using soft robotics

B. Methods

The first step to build the roadmap consisted of a literature review to obtain a general overview of the topic of interest. In this stage, the taxonomy that better unify the broad spectrum of the roadmap applications and objectives was defined. Surveys and whitepapers were used to extract this information. The abstract and keywords of these papers were used to define the taxonomy implemented. This taxonomy will be presented as a group of keywords.

Two databases and one keyword group were selected for this work. Only title, abstract, and keywords were considered during searching. These databases provide bibliometric research of different areas and are widely used to access various types of publications. The keyword group have two variations**.**

Keyword group – Scopus and Web of Science
“Soft Robotics” AND “Orthosis”
“Soft Robotics” AND “Orthotics”

Table 1 – Keyword Group

The sentences presented in tables 1 and 2 were connected using the logical operator AND, which imposes that it is necessary to satisfy both of the sentences in searching. The chosen databases were Scopus and Web of Science, the restricted publication period was from 2011 to 2021. This gives us a macro view of the development of such technologies in the last 10 years and can contribute to detecting a trend in the evolution of work in this area.

Analyzes related to the types of work and their absolute quantitative, temporal approaches, by area of knowledge, geographic and trend analysis will be presented.

IV. RESULTS

A. Database Overview

The first analysis was made considering results from keyword group. Besides being excellent platforms for searching scientific publications, the databases Web of Science and Scopus also provide statistical data about the articles. These data were considered in the results.

Number of Works	
Scopus	Web of Science
37	55

Table 2 – Number of works included by database

The methodology did not define an exclusion criterion for the search. However, the keywords used for searching on databases were defined considering logical operator AND.

Data that were repeated between the databases were observed, more specifically two studies, however there was no exclusion since the analysis is well segmented between databases and the general behavior of publications does not change due to this fact.

B. Analysis by document type

The first step was to analyze which types of documents the search returns, as expected there is a great predominance of articles, whether from journals or conferences that represent approximately 64% of all publications found.

Another interesting fact is the large amount of proceedings papers in the web of science base, demonstrating that there is a lot of work focused on the development of new applications, another data that corroborates this is the low number of revisions, indicating that the area is recent and still with few published works in relation to more established assistive technology approaches

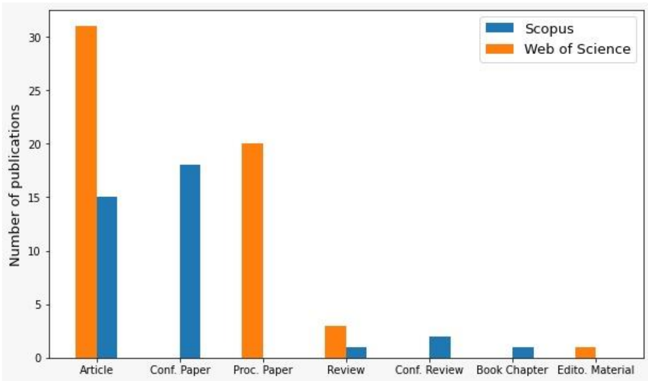

Figure 1 – Analysis by document type.

C. Analysis by research areas

This section is a guide for all areas involved in the application of soft robotics in orthotics in the databases defined in the methodology, despite the areas being defined by each base, generating segmentations that are different even if they compose the same area of knowledge. Even so, we believe that this is an important fact to elucidate the development of the state of the art in soft robotics and orthotics.

Figures 2 and 3 show the areas of knowledge that each work covers in each of the defined databases, for Scopus and web of science, respectively. As expected, there is a great predominance of works in the engineering area in both bases, robotics is the area that covers most works in the Web of Science, unfortunately there is no such area defined in

Scopus. Even so, several engineering works are in the mechatronics sub-area, a general area of robotics.

Through a non-trivial view, it is possible to observe the inclusion of several areas that are not so closely related to assistive technology or even biomedical engineering, such as education, social sciences, transport, telecommunications, among others. This point reinforces the incorporation of soft robotics by the most diverse areas as stated in the introduction, the soft features come to overcome challenges that are more difficult with approaches based on hard robotics.

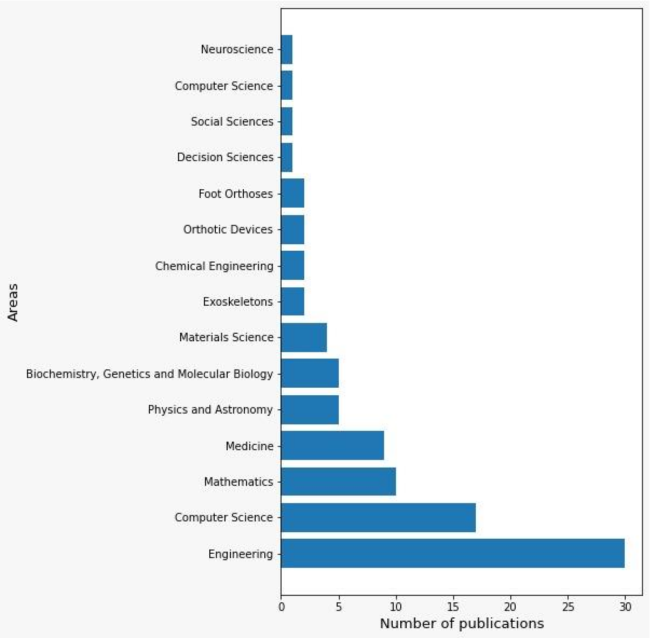

Figure 2 – Analysis by research area (Scopus).

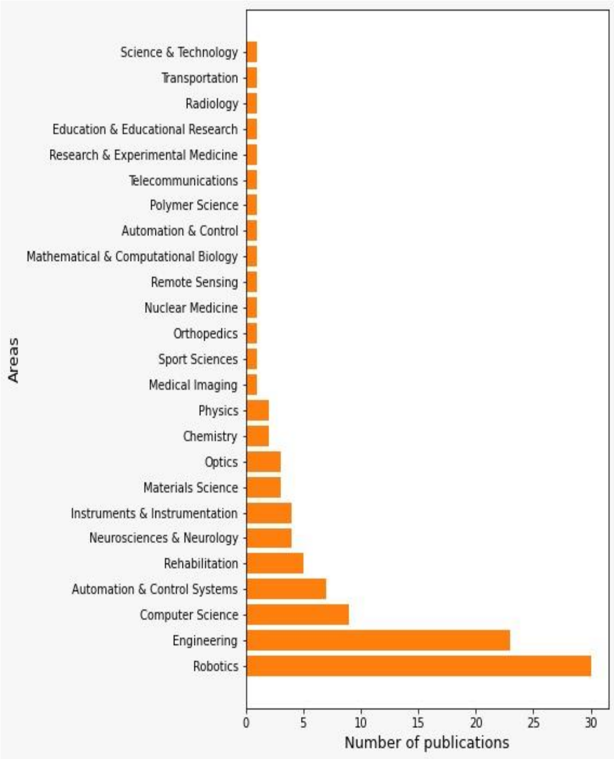

Figure 3 – Analysis by research area (Web of Science).

D. Geographical Analysis

Regarding geographic analysis, the predominance of the United States in scientific production on soft robotics and orthotics is remarkable, this country has large development centers in biomedical engineering, robotics and assistive technology, which makes the data show such behavior.

The countries that produce more after the United States in our survey were: Brazil, China and Singapore in the Scopus and South Korea, Brazil, Singapore, China, Italy and England in the Web of Science.

Despite Europe having reference centers in assistive technology, not many works were observed following the keywords in the cited bases, as will be discussed in future perspectives, this is a point to be evaluated to reinforce the insertion of new bases in future research.

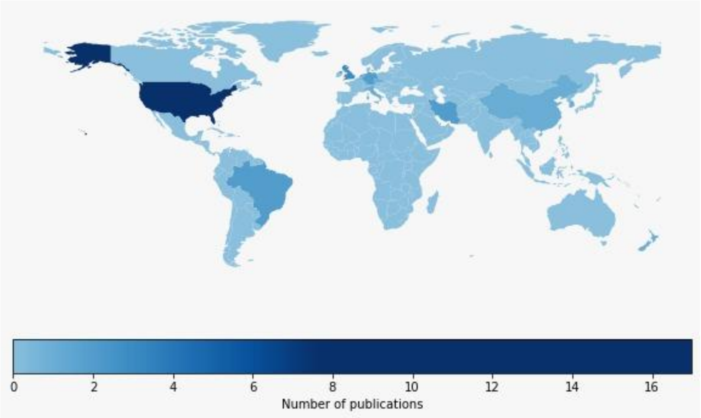

Figure 4 – Geographical Analysis (Scopus).

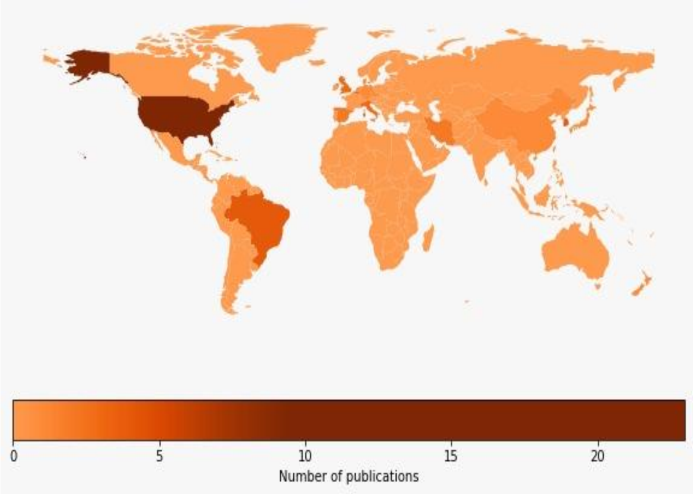

Figure 5 – Geographical Analysis (Web of Science).

These results are encouraging if evaluated from a regional perspective, considering that Brazil is one of the few nations that was highlighted in both bases, showing the development of work in assistive technology with modern technologies tracing even more advanced stages in the development of orthotic devices. The development of Biolab partnerships with institutions in Singapore and the United States is also noteworthy. evidencing the creation of links between institutions in countries that have published the most works in this field according to our search methodology.

E. *Quantitative Analysis*

This segmentation of the data is possibly the most obvious but very insightful, in it we present the number of works published per year in both databases and, despite the factors that we will discuss, a growing behavior is observed that suggests more development in the area.

Nonetheless, there are some punctual factors in time where in the short term the growth trend was not followed, the first period is the transition from 2017 to 2018, the average number of publications, which was 5 in each base consulted for two years, dropped to just two works per base per year, a decrease of 60%, however the data set is still very scarce and this still does not represent well the behavior of the period, this question will be resolved with the insertion of new bases in a future study.

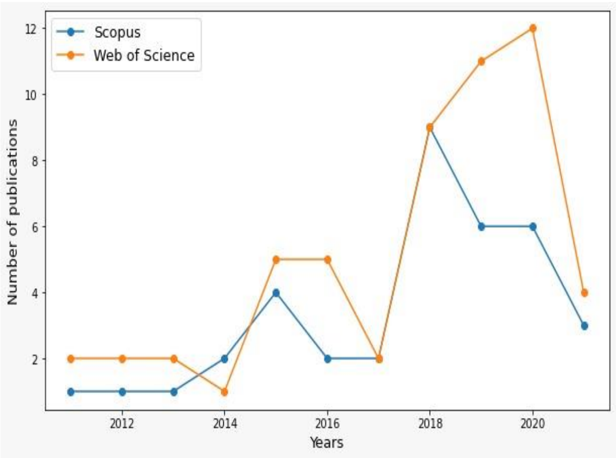

Figure 6 – Quantitative Analysis.

Another short-term period that does not correspond to the macro growth trend is the 2020-2021 biennium, but the explanation for these factors is more feasible, on the one hand we are facing the coronavirus pandemic, as we have seen, most of the works have a practical nature to be developed in person in the laboratories, we believe that the safety and distancing measures delayed the development of the work and their tests, contributing to a smaller number of publications in the area.

Furthermore, the year 2021 is still ongoing, it is unreasonable to compare a year where there are only seven months of analysis (until July) with years where publications took place throughout the year. Unlike the previous period, we believe that this behavior will be observed in the bases that will be included in the future

F. *Prediction Analysis*

A predictive analysis was performed using the data collected from both databases in order to prove the ascendant development of the field. Finally, the data presented in the previous topic were used in linear and logistic regressions to prove the growing behavior of works in the area and estimate the number of works in the coming years.

It is important to emphasize that although partial publications from 2021 are plotted in the dot-shaped graph, they were not used in the input vector of the regressions for the reasons mentioned above, mainly due to the fact that the entire year has not passed, this would generate a bias of inequity between the values used.

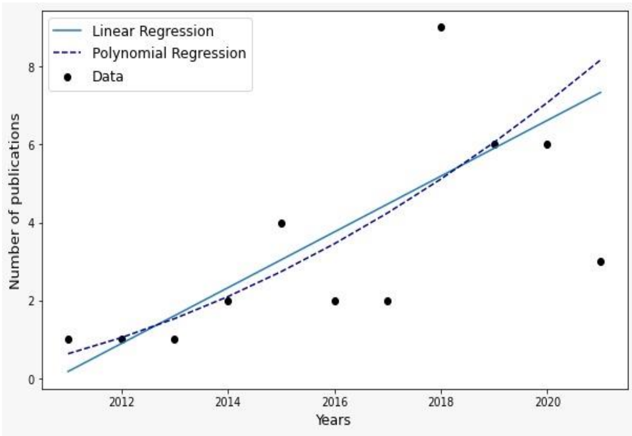

Figure 7 – Prediction Analysis (Scopus).

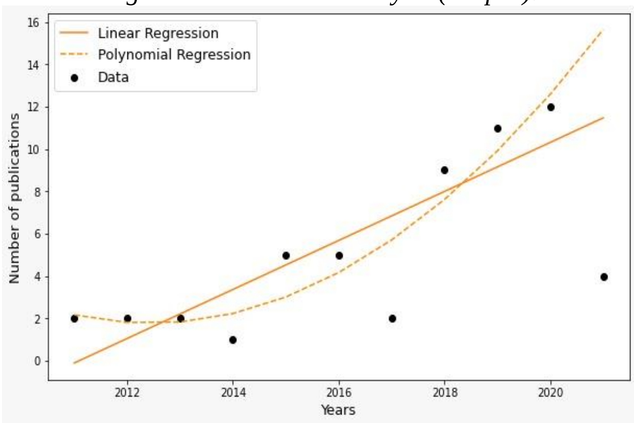

Figure 8 – Prediction Analysis (Web of Science).

It is important to emphasize that although partial publications from 2021 are plotted in the dot-shaped graph, they were not used in the input vector of the regressions for the reasons mentioned above. This generates a comparison factor between the number of works published so far and the estimated regressions.

It can be observed that for Scopus, around 7 papers published using linear regression and 8 papers using polynomial regression were expected. While for the Web of Science database, approximately 12 works using linear regression and 16 using polynomial regression, an accentuation due to the large increase in works published on this basis between 2017 and 2020

G. *Database Limitations*

Web of Science and Scopus are well known worldwide platforms used for searching scientific contents. These databases index scientific journals, books and conference proceedings, and they provide relevant material for bibliography review. However, it is impossible to assure that these platforms have all scientific ever published in the world. In other worlds, the discussions made in this paper were based on the results obtained from these two databases. Therefore, the results represent a significant overview about the topic, but probably they did not consider all publications.

H. *Applications and Future*

As previously discussed, roadmap provides interesting analyses regarding metrics and quantitative paper assessment. These considerations are extremely useful to comprehend the development stage of a certain topic or area, for instance. However, it is also crucial to qualitatively assess papers to identify and determine fundamental characteristics of this development. For future studies, we suggest to combine the results obtained here with a qualitative analysis about soft robotics in orthotic development.

V. CONCLUSION

Soft Robotics in orthosis applications shows an increase of interesting outcomes in recent years. This roadmap highlights an impressive growth of researches related to Soft Robotics and orthotic development, and evidences that use of soft robotics principles could significantly improve motor rehabilitation and usability in a general way. The bibliometric results present that soft robotics was still not widely explored by the orthotic scientific community. Therefore, soft technologies are a potential tool to surpass many challenges faced by orthosis development.

REFERENCES

[1] Shurr, D. G., Michael, J. W., & Cook, T. M. (2002). Prosthetics and orthotics. Upper Saddle River, NJ, USA: Prentice Hall. .

[2] Hoekstra, T. J. (2019). Case Studies Exploring Three Fundamental Stages of Product Development of Different Biomedical Engineering Technologies (Doctoral dissertation, University of South Dakota).

[3] Peaco, A., Halsne, E., & Hafner, B. J. (2011). Assessing satisfaction with orthotic devices and services: a systematic literature review. JPO: Journal of Prosthetics and Orthotics, 23(2), 95-105.

[4] Cianchetti, M., Laschi, C., Menciassi, A., & Dario, P. (2018). Biomedical applications of soft robotics. Nature Reviews Materials, 3(6), 143-153.

[5] de Souza, L. B., M.D.F.C., Borschiver, S.: Formas de onda e o programa rds-defesa:Proposta e resultados do roadmap tecnolgico do lte para aplicaes militares. XXXVISimposio Brasileiro de Telecomunicaes e Processamento de Sinais - SBrt2018 (2018).

[6] Kostoff, R.N., Schaller, R.R.: Science and technology roadmaps. IEEETransactions on Engineering Management 48(2), 132–143 (May 2001).https://doi.org/10.1109/17.922473.