Sliding mode and variable structure filters for signal processing: a literature review

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ABSTRACT

This paper will conduct an exhaustive analysis of sliding mode and variable structure filters, essential methodologies employed in signal processing that solve problems noisy and volatile environments induces. This study brings into focus the very foundations and practicality of interference filters by professional exploration of the theoretical basis, the extent of practical implementation, and the present research frontiers. It also emphasizes the critical role these filters play in making signal processing system more precise, adaptable, and resilient. The Sliding mode and the variable structure filters are optimal in the field of nonlinear problems that are augmented by interferences. These are what their purpose in noise reduction, error minimization and the system stability is. Review encompasses a wide range of applications, from robotics, aerospace to telecommunication with the aim to emphasis the variety and successfully of the filtering techniques when the signal processing is carried out in complex situations. The synthesis of the most recent achievements of the technology and discovery of the potential future directions passed down the concept of this work. The aim is to provide a push to developers to promote the implementation of the advanced application-specific solutions. And this discussion also demonstrates the flexible character that helps meet the demands of dynamic signal processing environments, forming the foundation for the next advanced systems that are adaptive and robust.

Keywords: Estimation theory**,** robust estimation, optimal estimation, signal processing, variable structure filter, sliding innovation filter

1. INTRODUCTION

As in signal processing, where the paramount of crucial and groundbreaking discoveries revolves around rudimentary issues of filtering techniques in the context of noisy and conflicting systems, the effective methodologies aiming at achieving the desired accuracy and precision are what is put in the spotlight [1-24]. Aside many applications of filter [25-52], the sliding mode and variable structure filters are regarded as the vital implementations that provide the integration of certain qualities such as precision [52-68], flexibility [69-72], and robustness [73-76]. These methodologies have indeed become a venerable issue in the practice of the improvement of accuracy and reliability through signal processing systems which have usually been faced with a major challenge of non-linearities and disturbances that have made linear filtering ineffective [77-94].

This article deals with both sliding mode and variable structure filters that not only denote areas of great development but and up till date signal processing sphere. Through going into the theoretical basis, practical implementations, and the most current research trends, is our aim to give a holistic understanding of these approaches.

2. METHODOLOGY

As we can in Figure 1, this study employed a comprehensive methodological approach [95-112] which enables better insight into the progress and contexts of application of sliding mode and variable structure filters, for a coupled picture in order to realize the stage of development and status quo. First we did a detailed searching of academic publications and articles on signal-to-noise ratio and its applications in signal processing using the widely known “Scopus” database which is known for containing a large collection of scientific and technical research articles. Strategic keyword selection around "sliding mode filter," "variable structure filter," "signal processing applications," as well "nonlinear filtering

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techniques" made it possible to capture most of the publications, both the classic primary sources and the original research results, and finally sawed work from the domain of sliding mode variable structure filter completed.

Thereafter well-coordinated scan and careful pick based on suitability to the subject under research, the recent publication, and impact of the citation was performed. This allowed studies to be absorbed deeply into the research in question, thereby resulting into summation of a diversified range work that was already well-cited and the current development. This helped maintain a balanced outlook in study of sliding mode and variable structure evolution in signal processing.

The second step of our bibliometric analysis phase was takig at the detailed level. We aimed to identify any emerging research trends, diy patterns, and thematic clusters within the sliding mode and variable structure research area. Such an analysis proved to be a turning point in unearthing the grand themes of sliding mode and variable structure research, discovering the untapped territories and plotting the routes its development will take, in order to realize the goal of understanding the field trends and indication of more promising areas in future researches.

The methodology in this regard entailed the finalisation and presentation of findings from the Bibliometric analysis which served as a powder keg of the progress made, technological development and avenue for novel research in the scope of sliding modes and variable structure filters, for signal processing. What stands out from these syntheses is the contribution, evolution, and trends identified in individual fields and at the same time, the gaps within the current literature as a basis for future inquiries. This amalgamated information is a key capsule for researchers, engineers and policy makers active in the area of signal processing technologies. The developed resource serve as useful reference material for the participants and in turn it allows to structure future discussions and work in this field.

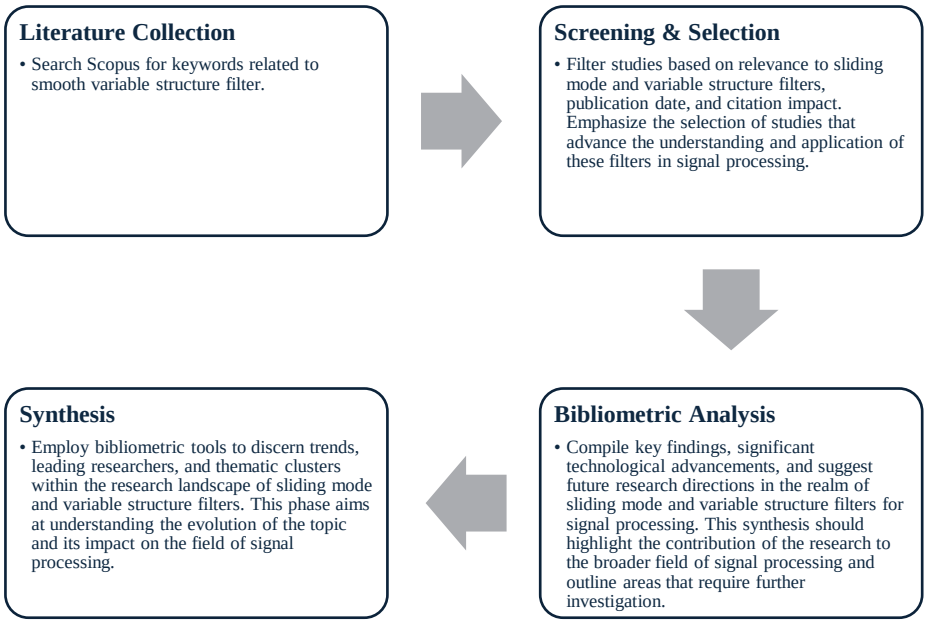

Figure. 1 Research methodology

3. RESULTS AND DISCUSSION

The representation of the study landscape with sliding units and structure function in Figure 2 by using VOSviewer depicts prominently some significant recurrent themes, methodology and technology which shape the research have a key role to play in the field. Clustering, labeling, and weight attribution data are used to show what these findings represent, and thereafter, implications and suggestions for future studies and implementations are brought up. Research is divided into six clusters of which each serves for pressing issue. A complex filtering strategy is that is used is the most suitable technique for noisy channels with high or distortion of signals. It, more especially, puts more emphasis on variable structure

filters expected to have a high degree of smoothness. The second group takes a close look at the control systems and actuators, illustrating a prominent position of Kalman filters in state estimation for the purpose of control. The remaining group shows the research community pursuing nonlinear systems analyses and neural networks for the purposes of parameter inference and adaptation rendering the models more adaptive, intelligent and therefore adaptive.

The last two group touch upon the area of rational data processing and application of adaptive Kalman filtering techniques in battery management and signal processing, holding the fifth group to the significance of estimation and filtering in robotic sense and autonomous mobility. The sixth cluster considers the theory of model uncertainty and stable estimations. The ascendency of estimation methods, the fusion of machine learning technology, robustness and uncertainty handling, and referencing both concrete and futuristic technologies in the applications domains outlines the diversity of field remit, from energy storage to autopilot systems.

This analysis presents a college environment that is rich in diversity of disciplines, thanks to the intersections between classical control theory, estimation algorithms, and modern machine learning, pointing for a growing the direction of more intelligent, adaptive and resilient signal processing and control system. Future research could be considered to boost machine learning confluence, handle uncertainty in unusual zones and aim for innovative cross-interdisciplinary uses. There presents is a trajectory which is powerful systems aimed at facing the emergence of the realities of modern technological environments, highlighting the foci on the current research and suggestions direction for future pursuits.

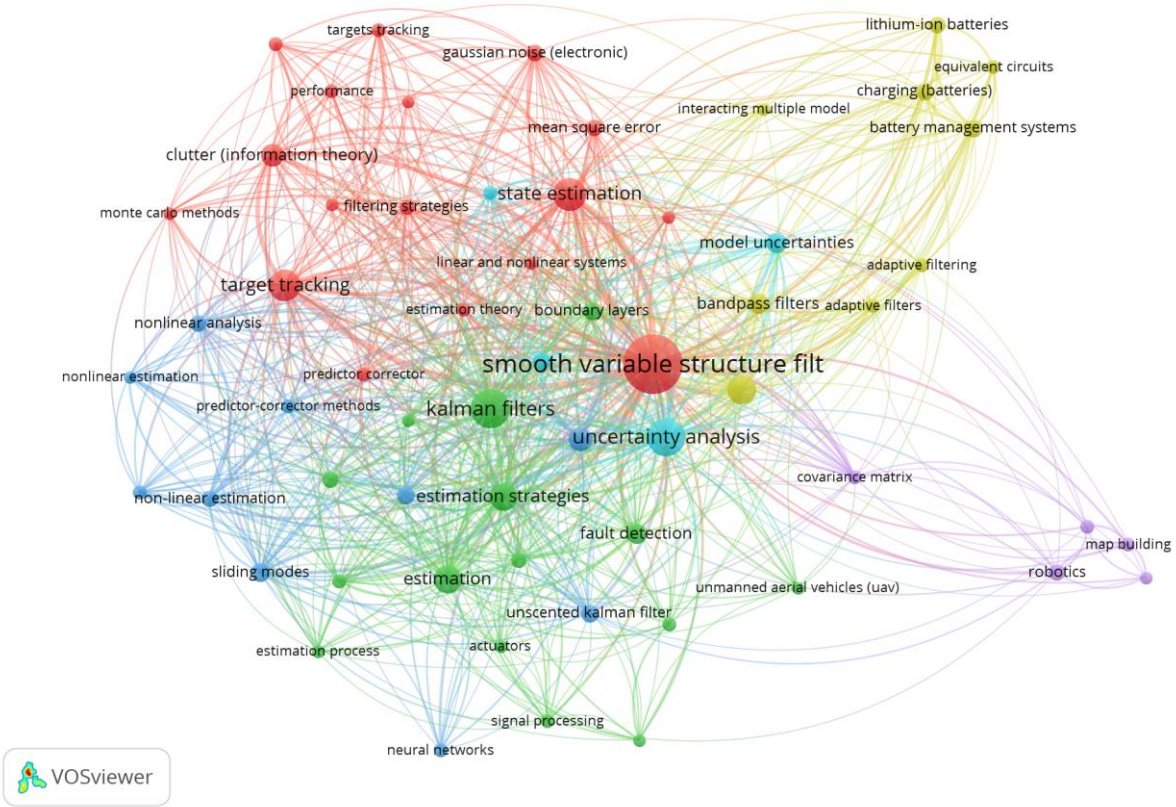

Figure 2 Thematic Clusters of Top Keywords

4. CONCLUSION

In conclusion, this comprehensive review of sliding mode and variable structure filters for signal processing elucidates a significant shift towards integrating advanced filtering techniques with machine learning to address complex challenges in signal processing and control systems. The bibliometric analysis reveals a multidisciplinary approach, emphasizing the critical need for robust, adaptable methodologies capable of handling uncertainties in dynamic environments. Highlighting key areas such as estimation techniques, nonlinear system analysis, and the application of these technologies in diverse domains, from energy storage to autonomous navigation, the study underscores the evolving landscape of signal processing. Future research directions point towards enhancing the integration of machine learning, addressing uncertainties in emerging technological fields, and exploring new applications, setting the stage for more intelligent, adaptive, and resilient signal processing solutions. This trajectory not only reflects the current state of research but also charts a path for future advancements in the field.

Declaration

The final draft of this research paper has undergone a rigorous proofreading process, which included the utilization of advanced artificial intelligence (AI) technology.

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