Unscented Kalman Filter in Chaotic Digital Communication- A Robust Spread

Khaled Obaideen[1], Mohammad AlShabi[2*], S. Andrew Gadsden[3] and Talal Bonny[4]

[1]Bio-Sensing and Bio-Sensors group, Smart Automation and Communication Technologies, RISE, Sharjah, United Arab Emirate; [2]Department of Mechanical and Nuclear Engineering, University of Sharjah, Sharjah, United Arab Emirates; [2]Department of Mechanical Engineering, McMaster University, Canada; [4]Department of Computer Engineering, University of Sharjah, United Arab Emirates

Abstract

This study provides a bibliometric analysis of the Unscented Kalman Filter (UKF) within chaotic digital communication, highlighting its significance and evolving role in enhancing the robustness of signal processing in unpredictable environments. Through a systematic review of literature from key databases and a detailed bibliometric examination, we trace the UKF's development, applications, and its intersection with various research themes, including chaos synchronization and nonlinear filtering. The findings underscore the UKF's importance in addressing the complexities of chaotic systems, revealing its impact across algorithms, chaos theory, and secure digital communication strategies. This analysis not only showcases the UKF's practical advantages and theoretical contributions but also positions it as a crucial tool for future advancements in digital communication technologies. The study encapsulates the UKF's potential to revolutionize signal processing by leveraging chaos for improved system performance, emphasizing the need for continued interdisciplinary research to harness this potential fully.

Keywords: Unscented Kalman Filter, Chaotic, VOSviewer, Bibliometric

1. Introduction

In the ever-evolving field of digital communication, particularly within the chaotic and unpredictable environments that define modern signal processing, the Unscented Kalman Filter (UKF) emerges as a beacon of robustness and precision [1-25]. The UKF, building upon the foundational principles of the classic Kalman Filter (KF) [1, 26-52] while adeptly navigating the nonlinearities inherent in real-world data, introduces a novel approach to enhancing the reliability and accuracy of spread spectrum communications amidst chaos. This paper delves into the heart of chaotic digital communication systems, where the UKF is applied to tackle the challenges posed by dynamic and unpredictable signal environments.

Chaotic systems, characterized by their sensitivity to initial conditions and apparent randomness, pose significant hurdles for traditional filtering and signal processing techniques [53-56]. The UKF, with its unique capability to estimate the state of a nonlinear system without linearizing the process or measurement functions, offers a promising solution to these challenges. By employing a deterministic sampling technique, the UKF provides a more accurate and computationally efficient means of predicting system states, thus significantly enhancing the performance of digital communication systems operating under chaotic conditions [57-81].

This bibliometric study highlights the UKF's key role in improving chaotic digital communication, emphasizing its effectiveness against system nonlinearities and uncertainties. By reviewing extensive literature, it demonstrates the UKF's impact on enhancing communication robustness and reliability in unpredictable chaotic scenarios.

2. Methodology

As we can see in Figure 1, our methodology for investigating the UKF's role in chaotic digital communication encompasses a unified, systematic approach, beginning with an exhaustive Literature Collection phase across databases such as IEEE Xplore, Google Scholar, and Elsevier's ScienceDirect to include peer-reviewed articles, conference proceedings, and key texts focusing on UKF's intersection with chaotic digital communication and

*malshabi@sharjah.ac.ae

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robust spread spectrum techniques. In the Screening & Selection stage, literature is carefully assessed for relevance, recency, and impact, ensuring alignment with our research goals and the significance of UKF in chaotic signal processing. The subsequent Bibliometric Analysis employs advanced tools to delineate the research landscape, identifying seminal works, leading contributors, and evolving trends, thus crafting a narrative around UKF's development and application in challenging communication scenarios [82-89]. Finally, the Synthesis phase amalgamates these insights, critically reviewing methodologies, outcomes, and theoretical implications to discern UKF's potential, limitations, and avenues for future exploration. This cohesive methodological framework not only deepens our understanding of UKF's contributions to digital communication in the face of chaos but also propels forward-looking research trajectories aimed at enhancing system robustness and reliability.

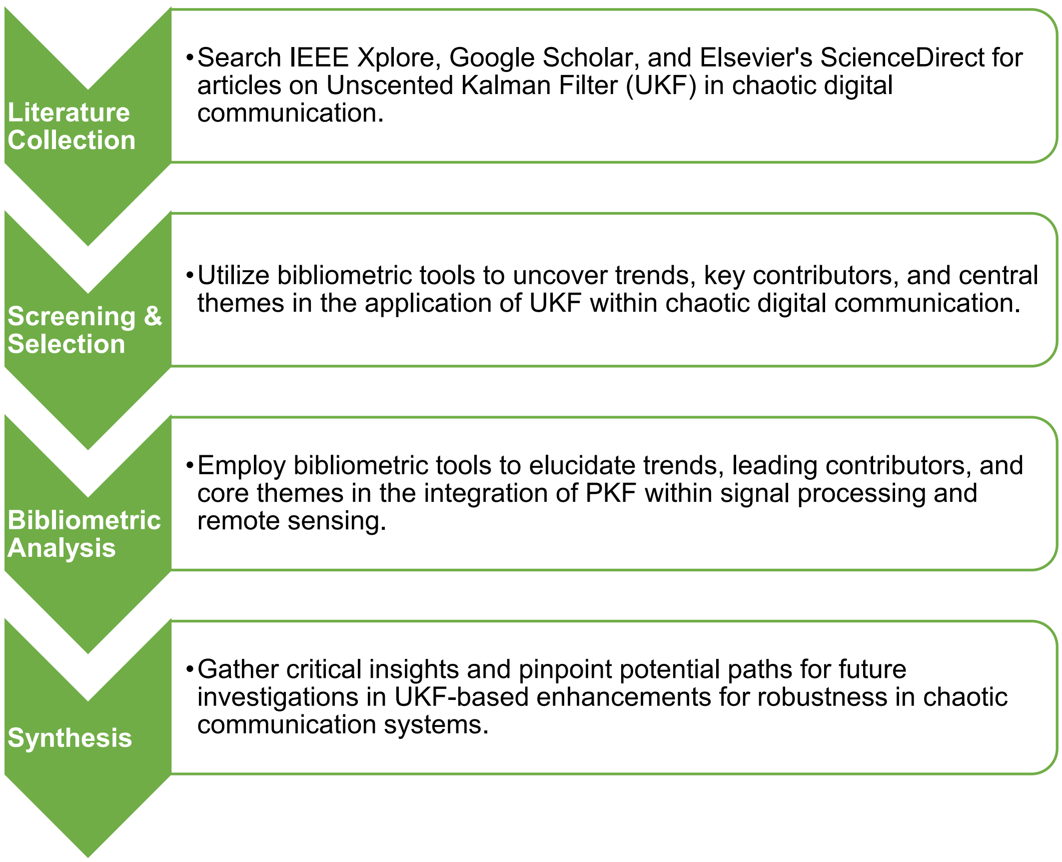

Figure 1 Research methodology

3. Results and discussion

As we can see in Figure 2, the VOSviewer analysis of the UKF in chaotic digital communication uncovers a diverse array of research topics, emphasizing its significant role across various themes such as algorithms, chaos synchronization, and chaos theory. The UKF stands out for its crucial function in nonlinear filtering within chaotic systems and as a fundamental methodology in the field, demonstrated by its dominant presence in the literature [67, 68, 73, 78, 90-100]. Its application in parameter estimation and addressing chaotic communications challenges highlights its importance.

This analysis shows a wide-ranging, interdisciplinary research effort, with a notable focus on understanding and utilizing the properties of chaos to improve communication systems. The repeated emphasis on chaos theory across different clusters underlines the critical role of theoretical frameworks in advancing the practical aspects of chaotic signal processing and communication.

Significant attention is given to nonlinear filtering, emphasizing the need for sophisticated filtering methods like the UKF to handle the unpredictability of chaotic signals. Research efforts are notably directed towards leveraging chaos for more secure and resilient digital communications, as seen in studies focused on chaotic communications and chaotic signal processing.

The incorporation of Kalman filters, especially the UKF, in chaotic time series and estimation techniques suggests their wider applicability beyond conventional signal processing, extending to time series analysis and predictions within chaotic environments. The exploration of particle filters, despite being less prevalent, indicates ongoing research into potentially complementary or alternative filtering approaches to the UKF.

Additionally, the intersection of neural networks with chaotic system analysis points towards a promising area for developing adaptive filtering and prediction methods, suggesting a fruitful crossover between machine learning and chaos theory. This intersection may lead to significant advances in utilizing chaotic dynamics for communication and signal processing.

Overall, the analysis indicates a vibrant interaction between theoretical research and practical application, positioning the UKF not merely as a tool but as a pivotal connection between algorithmic determinism and the unpredictable nature of chaotic systems. The ongoing efforts to decipher chaotic dynamics and enhance nonlinear filtering techniques underscore the potential for innovative communication strategies that capitalize on chaos's inherent unpredictability. This evolving landscape highlights the critical need for interdisciplinary collaboration and the continuous development of technologies like the UKF to navigate the challenges presented by chaotic digital communication environments effectively.

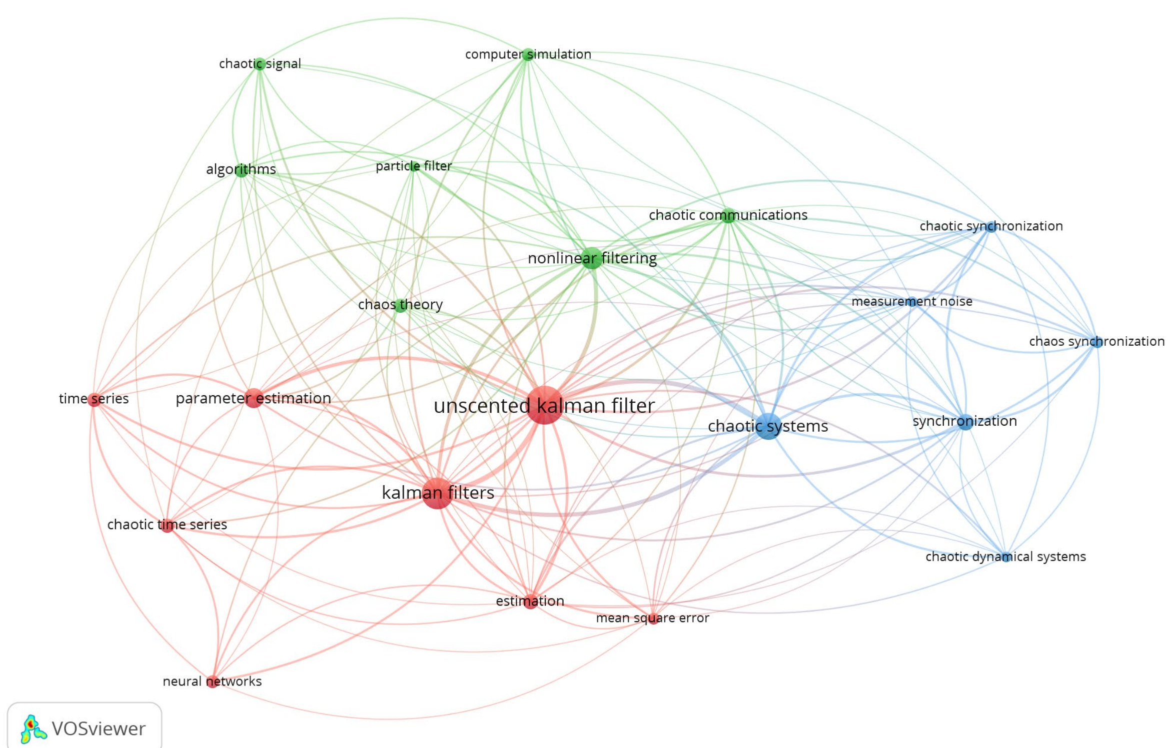

Figure 2 Thematic clusters of the top keywords

4. Conclusion

In conclusion, the comprehensive analysis of literature on the UKF within chaotic digital communication landscapes underscores its pivotal role as a versatile and powerful tool in navigating the complexities of chaotic systems. The research showcases the UKF's significant contributions to enhancing the robustness and reliability of communications in unpredictable environments, driven by its superior nonlinear filtering capabilities. The synthesis of findings from diverse disciplines highlights the importance of interdisciplinary approaches in advancing the field, revealing the UKF as a critical bridge between theoretical insights and practical applications. As we continue to explore the boundaries of chaotic dynamics and develop innovative solutions, the UKF stands out as a cornerstone technology, promising to shape the future of digital communication by leveraging the inherent unpredictability of chaos for improved security and efficiency. This body of work not only celebrates the achievements to date but also sets the stage for future explorations, emphasizing the ongoing need for research and development in harnessing the full potential of the UKF within the ever-evolving domain of chaotic digital communication.

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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