EXPLORING THE OPTIMAL POTENTIAL OF TRANSIENT REFLECTION METHOD THROUGH MEL-FREQUENCY CEPTRUMS COEFFICIENT AND ARTIFICIAL NEURAL NETWORK FOR LEAK DETECTION AND SIZE ESTIMATION IN WATER DISTRIBUTION SYSTEMS

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SUPERVISOR'S DECLARATION

We hereby declare that We have checked this thesis/project* and in my/our* opinion, this thesis/project* is adequate in terms of scope and quality for the award of the degree of Doctor of Philosophy.

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I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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AUTHOR

ABSTRAK

Sistem saluran paip air adalah infrastruktur kritikal yang menyediakan air yang boleh diminum kepada masyarakat. Reka bentuk dan pengendalian sistem ini adalah kompleks dan memerlukan pertimbangan yang teliti terhadap pelbagai faktor, seperti kebolehpercayaan sistem. Penyelenggaraan dan pemeriksaan tetap saluran paip dan komponen lain adalah perlu untuk mengelakkan kebocoran dan memastikan sistem beroperasi dengan berkesan. Pengesanan cekap dan anggaran tepat kebocoran dalam sistem pengagihan air adalah penting untuk mengekalkan integriti dan kefungsian infrastruktur. Penyelidikan ini bertujuan untuk mengeluarkan potensi penuh kaedah pantulan sementara melalui penyepaduan teknik Mel-Frequency Cepstral Coefficients (MFCC) dan Rangkaian Neural Buatan (ANN) untuk pengesanan kebocoran dan anggaran saiz dalam sistem pengagihan air. Dengan memanfaatkan gabungan kuasa pemprosesan isyarat dan pembelajaran mesin, kajian ini bertujuan untuk memajukan metodologi terkini untuk pengesanan kebocoran dan anggaran saiz, menyediakan pendekatan yang lebih tepat dan cekap berdasarkan kaedah pantulan sementara. Objektif penyelidikan ini adalah tiga kali ganda. Pertama, penyelidikan meneroka aplikasi MFCC sebagai teknik pemprosesan isyarat untuk mengekstrak maklumat penting daripada isyarat pantulan sementara. Isyarat pantulan sementara membawa pandangan berharga tentang ciri-ciri sistem pengagihan air dan boleh membantu dalam mengenal pasti kebocoran. Objektif kedua penyelidikan ini adalah untuk menyiasat dan memilih ciri penting yang diperoleh daripada isyarat pantulan sementara yang mencerminkan sifat saiz kebocoran. Objektif ketiga penyelidikan ini adalah untuk membangunkan dan mengesahkan model berasaskan ANN untuk anggaran saiz kebocoran yang memanfaatkan kuasa ciri TRM yang diekstrak. Untuk mencapai objektif ini, eksperimen dan analisis yang meluas akan dijalankan menggunakan kaedah pantulan sementara yang diperoleh daripada sistem pengagihan air skala makmal. Data akan dikumpul daripada pelbagai saiz kebocoran. Set data yang dikumpul akan berfungsi sebagai asas untuk melatih dan mengesahkan model ANN yang dibangunkan. Metrik penilaian prestasi, seperti ketepatan, ketepatan, ingat semula dan ralat kuasa dua min, akan digunakan untuk menilai keberkesanan dan kebolehpercayaan teknik pengesanan kebocoran dan anggaran saiz. Hasil yang diharapkan daripada penyelidikan ini termasuk kemajuan dalam pengesanan kebocoran dan teknik anggaran saiz dalam sistem pengagihan air. Penyepaduan teknik MFCC dan ANN berpotensi meningkatkan ketepatan dan kecekapan pengesanan kebocoran dengan ketara, yang membawa kepada pengenalpastian dan pengurangan kebocoran tepat pada masanya. Model anggaran yang dibangunkan boleh membantu dalam menilai keterukan kebocoran, membolehkan peruntukan sumber yang lebih berkesan untuk aktiviti pembaikan dan penyelenggaraan. Akhirnya, penemuan penyelidikan ini akan menyumbang kepada peningkatan pengurusan sistem pengagihan air, menggalakkan pemuliharaan air dan meminimumkan kesan buruk kebocoran terhadap infrastruktur dan alam sekitar. Kesimpulannya, penyelidikan ini berusaha untuk mengeluarkan potensi penuh kaedah pantulan sementara melalui penyepaduan teknik MFCC dan ANN untuk pengesanan kebocoran dan anggaran saiz dalam sistem pengagihan air. Hasil penyelidikan ini berpotensi memberi manfaat yang ketara kepada pihak berkuasa pengurusan air, utiliti, dan penyelidik yang bekerja dalam bidang pengurusan dan pemuliharaan sistem pengagihan air.

ABSTRACT

Water pipeline systems are critical infrastructures that provide potable water to communities. The design and operation of these systems are complex and require careful consideration of various factors, such as system reliability. Regular maintenance and inspection of pipelines and other components are necessary to prevent leaks and ensure that the system operates effectively. The efficient detection and accurate estimation of leaks in water distribution systems are crucial for maintaining the integrity and functionality of the infrastructure. This research aims to unleash the full potential of the transient reflection method through the integration of Mel-Frequency Cepstral Coefficients (MFCC) and Artificial Neural Network (ANN) techniques for leak detection and size estimation in water distribution systems. By leveraging the combined power of signal processing and machine learning, this study aim to advance the state-of-the-art methodologies for leak detection and size estimation, providing more accurate and efficient approaches based on transient reflection method. The objectives of this research are to explores the application of MFCC as a signal processing technique to extract vital information from the transient reflection signals. The transient reflection signals carry valuable insights into the characteristics of the water distribution system and can aid in identifying leaks. Furthermore to investigate and select significant features derived from the transient reflection signals that reflect the nature of leak size. Finally, is to develop and validate an ANN-based model for leak size estimation that harnesses the power of the extracted TRM features. To achieve these objectives, extensive experimentation and analysis will be conducted using transient reflection method obtained from laboratory scale water distribution systems. The data will be collected from various sizes of leaks. The collected dataset will serve as the foundation for training and validating the developed ANN model. Performance evaluation metrics, such as accuracy, precision, recall, and mean squared error, will be utilized to assess the effectiveness and reliability of the leak detection and size estimation technique. The expected outcomes of this research include advancements in leak detection and size estimation techniques in water distribution systems. The integration of MFCC and ANN techniques has the potential to significantly improve the accuracy and efficiency of leak detection, leading to timely identification and mitigation of leaks. The developed estimation model can aid in assessing the severity of leaks, enabling more effective allocation of resources for repair and maintenance activities. Ultimately, the findings of this research will contribute to the enhancement of water distribution system management, promoting water conservation and minimizing the adverse impacts of leaks on infrastructure and the environment. In conclusion, this research endeavors to unleash the full potential of the transient reflection method through the integration of MFCC and ANN techniques for leak detection and size estimation in water distribution systems. By leveraging signal processing and machine learning, this study aims to advance the state-of-the-art methodologies and provide more accurate and efficient approaches to address the challenges associated with leak detection and size estimation. The outcomes of this research have the potential to significantly benefit water management authorities, utilities, and researchers working in the field of water distribution system management and conservation.

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