ARAB ACADEMY FOR SCIENCE, TECHNOLOGY AND MARITIME TRANSPORT

College of Engineering and Technology

Construction and Building Engineering Department

CONDITION ASSESSMENT FOR INFRASTRUCTURE ASSETS USING BLOCKCHAIN 4.0

By

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A thesis submitted to AASTMT in partial fulfillment of the requirements for the award of the degree of

MASTER OF SCIENCE

in

CONSTRUCTION AND BUILDING ENGINEERING

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2023

DECLARATION

I certify that all the material in this thesis that is not my own work has been identified, and that no material is included for which a degree has previously been conferred on me.

The contents of this thesis reflect my own personal views, and are not necessarily endorsed by the University.

Name ……………………………………………………………………………

Signature ……………………………………………………………………………

Date ……………………………………………………………………………...

Dedication

I dedicate this thesis to my ***Parents***.

Acknowledgments

First and foremost, I would like to thank God, whose guidance has led me this far. My thanks also go to several people whose support helped me bring forth this work. I would first like to express my sincere thanks and gratitude to my professors and supervisors, Prof. ***Mohamed Ihab Elmasry*** and Prof. ***Ahmed Abdelmoty Elhakeem*** for their keen interest, extensive assistance, guidance, motivation, generous support, and close supervision throughout working on this thesis. It has been a great honor to work with them and to learn from their experience.

Also, I would like to thank my family for their emotional support and encouragement that helped me overcome any challenge. I would like to thank my father, ***Ahmed Handouka*** for his unconditional support, my mother for her love and continuous prayers that enlightened my path; and my siblings, Alaa, and Mohamed of whom I will always be proud.

Thank you,

Ahmed M. Handouka

Abstract

Infrastructure networks like roads, bridges, and buildings have considerable value in the nations' economies. Infrastructure networks have been modernized and gained complexity over time, putting owning organizations worldwide under pressure to ensure their proper functionality and sustainability. Infrastructure Asset Management is the key solution to this challenge. It is the process of maintaining, upgrading, and operating infrastructure assets cost-effectively through a set of functions. The main function is to determine the assets conditions in the network, whether the current ones or the projected future conditions. Such function as such is the key for making optimum decisions and developing priority plans over the planning horizon. Both current and future conditions are highly dependent on information and data management. This data management may be an obstacle confronts seeking rational repair strategies.

Blockchain technology gained fame with the introduction of the Bitcoin cryptocurrency in 2009. It is used as a data management mechanism to distribute and circulate Bitcoin transactions safely. Later, researchers extended the use of blockchain to other areas. Blockchain technology is rapidly evolving and as 2022 the latest generation of Blockchain, Blockchain 4.0 was introduced. It integrates Blockchain with AI, adding a robust computation and decision analysis dimension to its original data management capabilities.

This research introduces blockchain-based AI condition assessment framework, for monitoring and assessing the current condition and predicting the future condition of building infrastructure assets. The framework follows a four-step methodology, as such: (1) developing a permissioned blockchain network to manage and exchange asset information while boosting collaboration and coordination between relevant stakeholders; (2) incorporating chain-codes to regulate the Blockchain's behavior; (3) incorporating a trained, tested, and validated ANN model to the prediction chain code to perform analytics and predict asset conditions; and (4) validating the system's workability and performance using two case studies and a created frontend interface. The system's performance is technically evaluated in terms of transfer latency, privacy & security, storage size, and system scalability. The average latency for the writing and reading was less than 5000 and 2000 milliseconds, respectively. Also, the system has the capability to be upscaled at any time to accommodate the use case under consideration without the need to rebuild the whole system.

The two case studies for validation are a minor one of 134 doors and a major global one of 35 buildings' structural system. The machine learning models were developed using NeuroSolutions Software Version 6.0. The ANNs included in the chain codes of the two case studies showed a promising result with R^2 values of 0.99, 0.98, and 0.99 for training, cross-validation, and testing sets, respectively, for doors ANN. While R^2 values of 0.98, 0.99, and 0.93 for training, cross-validation, and testing sets, respectively, for the structural system ANN. Which proves the reliability of the system.

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Nomenclatures

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المستخلص

شبكات البنية التحتية مثل الطرق والجسور والمباني لها قيمة كبيرة في اقتصادات الدول. تم تحديث شبكات البنية التحتية واكتسبت تعقيدًا بمرور الوقت ، مما وضع المنظمات المالكة في جميع أنحاء العالم تحت ضغط لضمان وظائفها المناسبة واستدامتها. إدارة أصول البنية التحتية هي الحل الرئيسي لهذا التحدي. إنها عملية صيانة أصول البنية التحتية وتحديثها وتشغيلها بطريقة فعالة من حيث التكلفة من خلال مجموعة من الوظائف. وتتمثل الوظيفة الرئيسية في تحديد حالة هذه الأصول في الشبكة ، سواء كانت الحالة الحالية أو المستقبلية المتوقعة. هذه الوظيفة على هذا النحو هي المفتاح لاتخاذ القرارات المثلى وتطوير خطط الأولوية على مدى أفق التخطيط. تعتمد كل من الحالات الحالية والمستقبلية بشكل كبير على إدارة المعلومات والبيانات. قد تكون إدارة البيانات هذه عقبة تواجه البحث عن استراتيجيات إصلاح عقلانية.

اكتسبت تقنية قواعد البيانات المتسلسلة (Blockchain) شهرة مع ظهور عملة البيتكوين الافتراضية (Bitcoin) عام 2009. حيث تم استخدامها كآلية لإدارة البيانات لتوزيع وتداول تحويلات Bitcoin بأمان. في وقت لاحق ، وسع الباحثون استخدام قواعد البيانات المتسلسلة إلى مجالات أخرى. حيث تطورت تقنية قواعد البيانات المتسلسلة بسرعة، وفي عام 2022 تم تقديم أحدث جيل من قواعد البيانات المتسلسلة Blockchain 4.0 بحيث يتم دمج قواعد البيانات المتسلسلة مع الذكاء الاصطناعي ، مضيفًا بُعدًا ثوريا قويًا لتحليل البيانات اضافة إلى قدراتها فى إدارة البيانات.

يقدم هذا البحث إطار عمل لتقييم الحالة لاصول البنية التحتية باستخدام الذكاء الاصطناعي المستند إلى قواعد البيانات المتسلسلة، من أجل مراقبة وتقييم الحالة الحالية والتنبؤ بالحالة المستقبلية لأصول البنية التحتية للمباني. يتبع إطار العمل منهجية من أربع خطوات ، على النحو التالي: (1) تطوير شبكة blockchain مرخصة لإدارة وتبادل معلومات الأصول مع تعزيز التعاون والتنسيق بين أصحاب المصلحة المعنيين ؛ (2) إنشاء مجموعة من الاكواد لتنظيم عمل blockchain ؛ (3) دمج نماذج تقنية الشبكات العصبية الصناعية (ANN) مدربة ومختبرة في الاكواد شبكة blockchain لإجراء التحليلات والتنبؤ بحالة الأصول؛ و (4) التحقق من قابلية تشغيل النظام وأدائه باستخدام دراستي حالة وواجهة أمامية تم إنشاؤها. يتم تقييم أداء النظام تقنيًا من حيث وقت الاستجابة، الخصوصية والأمان، حجم التخزين واخيرا قابلية تطوير النظام. كان متوسط وقت الاستجابة لعمليات الكتابة والقراءة أقل من 5000 و 2000 مللي ثانية ، على التوالى. أيضًا ، يتمتع النظام بإمكانية الارتقاء في أي وقت لاستيعاب حالة الاستخدام قيد النظر دون الحاجة إلى إعادة بناء النظام بأكمله.

دراستا الحالة للتحقق من الصحة عبارة عن دراسة حالة ثانوية لعدد من 134 بابًا ودراسة حالة رئيسية لعدد 35 نظامًا هيكليًا لمباني قائمة. تم تطوير نماذج التعلم الآلي باستخدام الإصدار 6.0 من برنامج Neuro-Solutions. أظهرت نماذج ANN المدرجة في كود السلسلة الخاصة بدراستي الحالة نتائج واعدة بقيم R2 تبلغ 0.99 و 0.98 و 0.99 لمجموعات التدريب والتحقق المتبادل و الاختبار، على التوالي، للأبواب. بينما قيم R2 تبلغ 0.98 و 0.99 و 0.93 لمجموعات التدريب والتحقق المتبادل والاختبار، على التوالي، للنظام الهيكلي. مما يثبت موثوقية النظام.

إقرار الباحث

أقر بأن المادة العلمية الواردة في هذه الرسالة قد تم تحديد مصدرها العلمي وأن محتوى الرسالة غير مقدم للحصول علي أي درجة علمية أخرى، وأن مضمون هذه الرسالة يعكس أراء الباحث الخاصة وهى ليست بالضرورة الآراء التي تتبناها الجهة المانحة.

الاسم ....

التوقيع ....

التاريخ ....

الأكاديمية العربية للعلوم والتكنولوجيا والنقل البحري

كليـــة الهندســـة والتكنولوجيــــــــا

قسم هندسة التشييد و البناء

تقييم الحالة لاصول البنية التحتية باستخدام نهج قواعد البيانات المتسلسلة 4.0

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القاهرة

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