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Thème

Cognitive Digital Twins

for IoT Resilience and Prevention

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Dedication

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Abstract

The concept of Digital Twins (DTs) has been evolving to include cognitive capabilities, leading to the emergence of Cognitive Digital Twins (CDTs).

CDTs are digital representations of physical systems that are augmented with cognitive capabilities to execute autonomous activities. They comprise a set of semantically interlinked digital models related to linking and retrieving heterogeneous data, as well as descriptive and simulation models. The CDT concept enhances the cognition capabilities of DTs with semantic technologies, enabling them to be more intelligent, comprehensive, and provide full lifecycle representation of complex systems.

This paper explores the potential of CDTs in enhancing perturbation resilience and maintenance. a super-Digital twin is realized that not only replicates the system's actions, but generates perturbations and anomalies to maintain and empower the system's security.

Keywords: Digital Twins; Cognitive Digital Twins ; Internet of Things; Resilience; Artificial Intelligence; Machine Learning; Deep Learning

Résumé

Le concept de Digital Twins (DTs) a évolué pour inclure des capacités cognitives, ce qui a conduit à l'émergence des Cognitive Digital Twins (CDTs). Les CDTs sont des représentations numériques de systèmes physiques qui sont enrichies de capacités cognitives pour exécuter des activités autonomes. Ils comprennent un ensemble de modèles numériques sémantiquement interconnectés liés à la liaison et à la récupération de données hétérogènes, ainsi que des modèles descriptifs et de simulation. Le concept de CDT améliore les capacités cognitives des DTs grâce aux technologies sémantiques, leur permettant d'être plus intelligents, exhaustifs et de fournir une représentation du cycle de vie complet des systèmes complexes.

Ce document explore le potentiel des CDTs dans l'amélioration de la résilience aux perturbations et de la maintenance. Un super-digital twin est réalisé, qui non seulement reproduit les actions du système, mais génère des perturbations et des anomalies pour maintenir et renforcer la sécurité du système. Le mémoire de master examine les possibilités offertes par les CDTs pour améliorer la résilience aux perturbations et la maintenance des systèmes complexes. Il propose également un cadre de recherche pour déterminer quand et comment un digital twin doit être enrichi de capacités cognitives. L'utilisation des CDTs dans les systèmes de fabrication est également explorée.

Mots Clés: Jumeaux numériques ; Jumeaux numériques cognitifs ; Internet des objets ; Résilience ; Intelligence artificielle ; Apprentissage automatique ; Apprentissage profond

ملخص

لقد تطور مفهوم التوائم الرقمية ليشمل القدرات المعرفية ، مما أدى إلى ظهور التوائم الرقمية المعرفية.

التوائم الرقمية المعرفية هي تمثيلات رقمية للأنظمة المادية التي يتم تعزيزها بالقدرات المعرفية لتنفيذ الأنشطة المستقلة. وهي تتألف من مجموعة من النماذج الرقمية المترابطة بشكل كبير والمتعلقة بربط واسترجاع البيانات غير المتجانسة ، فضلاً عن النماذج الوصفية والمحاكاة.
يعزز مفهوم التوائم الرقمية المعرفية القدرات الإدراكية للتوائم الرقمية باستخدام التقنيات الدلالية ، مما يمكّنهم من أن يكونوا أكثر وضوحًا وشمولية ويوفر تمثيلاً كاملاً لدورة الحياة للأنظمة المعقدة.

تستكشف هذه الورقة إمكانات التوائم الرقمية المعرفية في تعزيز مقاومة الاضطرابات وصيانتها. يتم تحقيق التوأم الرقمي الفائق الذي لا يكرر فقط إجراءات النظام ، ولكنه يولد الاضطرابات والشذوذ للحفاظ على أمان النظام وتمكينه.

الكلمات الرئيسية: التوائم الرقمية. التوائم الرقمية المعرفية. انترنت الأشياء؛ صمود؛ الذكاء الاصطناعي؛ التعلم الالي؛ تعلم عميق

List of Acronyms and Abbreviations

DT Digital Twin

IDMU Integral Digital Mock-Up

NASA National Aeronautics and Space Administration

IoT Internet of Things

GE General Electric

QoS Quality of Service

AI Artificial Intelligence

ML Machine Learning

ITU International Telecommunication Union

NGN Next-Generation Networks

RFID Radio-Frequency IDentification

BLE Bluetooth Low Energy

PLM Product Life-cycle Management

DTP Digital Twin Prototype

DTI Digital Twin Instance

PT Physical Twin

CMMs Coordinate Measuring Machine

VVA Verification, Validation and Accreditation

BD Big Data

DL Deep Learning

CPSs Cyber-Physical Systems

IT Information Technology

MAPE-K Monitor-Analyze-Plan-Execute over a shared Knowledge

KPIs Key Performance Indicators

CDT Cognitive Digital Twin

UI User Interface

MES Manufacturing Execution System

ERP Entreprise Resource Planning

WMS Warehouse Management System

API Application Programming Interface

NN Neural Network

KNN K-Nearest Neighbour

SVM Support vector machine

PCA Principal Component Analysis

SVD Singular Value Decomposition

HMM Hidden Markov model

MLPs Multilayer Perceptrons

CNNs Convolutional Neural Networks

CNN Convolutional Neural Network

RNNs Recurrent Neural Networks

LSTM Long Short-Term Memory

CSDT Cognitive Super-Digital Twin