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Thème

**The Use of Cognitive Digital Twins on an IoT System
for Edge Resilience and Anomaly Detection**

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Dedication

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Abstract

The concept of Digital Twins (DTs) has progressed to encompass cognitive abilities, resulting in the emergence and appearance of Cognitive Digital Twins (CDTs).

CDTs are virtual representations of tangible or physical systems that have been enhanced with cognitive capabilities to carry out independent activities and autonomous tasks. They consist of a collection of interconnected digital models that can handle various types of data and descriptive and simulation models. The idea of CDTs enhances the cognitive capabilities of DTs using semantic technologies, enabling them to become more intelligent, all-encompassing, and capable of providing a complete representation of complex systems throughout their entire life cycle.

In this Engineering degree report, the main aspects and appliance of Digital Twin (DT) in resilience and anomaly detection based Machine Learning and Deep Learning approaches have been presented in the form of a a state of the art and led to the presentation of an experimental work that consists of developing a Cognitive Super-Digital Twin (CSDT) which not only replicates the actions of a system but also generates perturbations and anomalies as a means to bolster the system's security and ensure its continuity. It can identify vulnerabilities and devise appropriate countermeasures. This proactive approach enables the system to adapt and fortify its security measures, mitigating potential risks and ensuring uninterrupted operation.

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

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Résumé

Le concept des Jumeaux Numériques (DT, pour Digital Twins) a évolué pour inclure des capacités cognitives, conduisant à l'émergence des Jumeaux Numériques Cognitifs (CDT, pour Cognitive Digital Twins).

Les CDTs sont des représentations numériques de systèmes physiques augmentées de capacités cognitives pour exécuter des activités autonomes. Ils comprennent un ensemble de modèles numériques sémantiquement interconnectés qui permettent de lier et récupérer des données hétérogènes, ainsi que des modèles descriptifs et de simulation. Le concept de CDT améliore les capacités cognitives des DT grâce aux technologies sémantiques, ce qui les rend plus intelligents, complets et capables de représenter l'ensemble du cycle de vie des systèmes complexes.

Dans ce rapport de diplôme d'ingénieur, les principaux aspects et applications des DT dans la résilience et la détection d'anomalies basées sur des approches d'apprentissage automatique et d'apprentissage profond ont été présentés sous la forme d'un état de l'art. Cela a conduit à la présentation d'un travail expérimental consistant à développer un CDT qui, non seulement reproduit les actions d'un système, mais génère également des perturbations et des anomalies afin de renforcer la sécurité du système et garantir sa continuité. Il peut identifier les vulnérabilités et élaborer des contre-mesures appropriées. Cette approche proactive permet au système de s'adapter et de renforcer ses mesures de sécurité, atténuant les risques potentiels et assurant un fonctionnement ininterrompu.

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

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ملخص

تطور مفهوم التوائم الرقمية (DTs) ليشمل القدرات المعرفية ، مما أدى إلى ظهور التوائم الرقمية المعرفية (CDTs).

CDTs هي تمثيلات رقمية للأنظمة المادية التي يتم تعزيزها بالقدرات المعرفية لتنفيذ الأنشطة المستقلة. وهي تتألف من مجموعة من النماذج الرقمية المترابطة لغويًا والمتعلقة بربط واسترجاع البيانات غير المتجانسة ، فضلاً عن النماذج الوصفية والمحاكاة. يعزز مفهوم CDT القدرات الإدراكية لـ DTs باستخدام التقنيات الدلالية ، مما يمكنهم من أن يكونوا أكثر ذكاءً وشموليةً ، ويوفر تمثيلاً كاملاً لدورة الحياة للأنظمة المعقدة.

في تقرير الدرجة الهندسية هذا ، تم تقديم الجوانب والأجهزة الرئيسية لـ Digital Twin (DT) في مناهج التعلم الآلي والتعلم العميق القائمة على المرونة والكشف عن الشذوذ في شكل حالة من الفن وأدت إلى تقديم عمل تجريبي التي تتكون من تطوير التوأم الرقمي الفائق المعرفي (CSDT) الذي لا يكرر فقط إجراءات النظام ولكنه أيضاً يولد الاضطرابات والشذوذ كوسيلة لتعزيز أمن النظام وضمان استمراريته. يمكنه تحديد نقاط الضعف واستنباط التدابير المضادة المناسبة. يمكن هذا النهج الاستباقي النظام من تكييف تدابير الأمانة وتعزيزها ، وتخفيف المخاطر المحتملة وضمان التشغيل دون انقطاع.

الكلمات الرئيسية: التوائم الرقمية. التوائم الرقمية المعرفية. انترنت الأشياء؛ الذكاء الاصطناعي؛ التعلم الآلي؛ تعلم عميق. الذكاء الاصطناعي؛ التعلم الآلي؛ 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 Enterprise Resource Planning

WMS Warehouse Management System

API Application Programming Interface

UCI University of California, Irvine

OS Operating System

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

HI Heat Index

AMQP Advanced Message Queuing Protocol

MQTT Message Queuing Telemetry Transport

SoS System of Systems

JSON JavaScript Object Notation