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Building a Corporate Memory for the Capitalization and Reuse of Maintenance Intervention Experiences

A Hybrid Approach Based on Transformers and Case-Based Reasoning

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Abstract

This thesis addresses the problem of the loss of knowledge and know-how in the field of industrial maintenance, and the drawbacks of corrective maintenance on the availability of production lines, taking the rotary kiln of a cement plant as a practical case. We propose an intelligent predictive-maintenance system based on a hybridisation of the forms of knowledge exploitation. On the *knowledge-extraction* side, a Transformer autoencoder learns the normal behaviour of the rotary kiln from an input formed of sixteen sensors, using six months of historian data, and detects the precursory signs of failure through the reconstruction error. On the *knowledge-engineering* side, case-based reasoning capitalises the interventions (deemed valid by the operators) into a corporate memory, providing an experience feedback that reuses the solutions of past failures similar to the current breakdown. On the *knowledge-management* side, our approach shifts the majority of interventions from corrective to preventive maintenance, guaranteeing the availability and reliability of the production lines. The proposed hybrid approach is implemented as a pipeline (Kafka, InfluxDB, Grafana, Prometheus) with graded and deduplicated alerts, together with an active-learning loop, driven by the operator, that retrains the model. The ultimate objective is the incremental construction of a corporate memory that solves the problem of expert unavailability.

Keywords: predictive maintenance, anomaly detection, Transformers, autoencoder, Case-Based Reasoning, corporate memory, rotary kiln.

Résumé

Ce mémoire traite le problème de la perte du savoir et savoir-faire dans le domaine de la maintenance industrielle, et des inconvénients de la maintenance corrective sur la disponibilité des lignes de production, en prenant le four rotatif d'une cimenterie comme cas pratique. Nous proposons un système intelligent de maintenance prédictive fondé sur une hybridation des formes d'exploitation de la connaissance. Côté extraction de connaissances, un auto-encodeur Transformer apprend le comportement normal du four rotatif suivant une entrée formée de seize capteurs, à partir de six mois de données d'historique, et détecte les signes précurseurs de défaillance suivant l'erreur de reconstruction. Côté ingénierie des connaissances, le raisonnement à partir de cas capitalise les interventions (jugées valides par les opérateurs) dans une mémoire d'entreprise, assurant un retour d'expérience pour réutiliser les solutions des défaillances passées similaires à la panne actuelle. Côté gestion des connaissances, notre approche fait passer la majorité des interventions d'une maintenance corrective à une maintenance préventive, garantissant la disponibilité et la fiabilité des lignes de production. L'approche hybride proposée est réalisée sous forme d'un pipeline (Kafka, InfluxDB, Grafana, Prometheus) avec des alertes graduées et dédupliquées, avec une boucle d'apprentissage

active, pilotée par l'opérateur qui réentraîne le modèle. L'objectif final est la construction incrémentale d'une mémoire d'entreprise résolvant le problème de l'indisponibilité des experts.

Mots-clés : maintenance prédictive, détection d'anomalies, Transformers, autoencodeur, raisonnement à partir de cas, mémoire d'entreprise, four rotatif.

ملخّص

تتناول هذه المذكّرة مشكلة فقدان المعرفة والدراية في مجال الصيانة الصناعيّة، وسلبيّات الصيانة التصحيحيّة على توفّر خطوط الإنتاج، متّخذةً الفرن الدوّار لمصنع إسمنت حالةً تطبيقيّة. نقترح نظامًا ذكيًّا للصيانة التنبّؤيّة يقوم على تهجين أشكال استثمار المعرفة. في **استخراج المعرفة**، يتعلّم مُرمِّزٌ تلقائيٌّ من نوع المحوّل (Transformer) السلوكَ الطبيعيَّ للفرن الدوّار انطلاقًا من دخلٍ مكوَّنٍ من ستّة عشر مستشعرًا، اعتمادًا على ستّة أشهرٍ من البيانات التاريخيّة، ويكشف العلامات المبكّرة للأعطال عبر خطأ إعادة البناء. وفي **هندسة المعرفة**، يقوم الاستدلال المبنيّ على الحالات برسملة التدخّلات (التي يُقرّ المشغّلون بصحّتها) في ذاكرةٍ مؤسّسيّة، بما يضمن عائدًا من الخبرة لإعادة استعمال حلول الأعطال السابقة المشابهة للعطل الحالي. وفي **إدارة المعرفة**، ينقل نهجُنا معظمَ التدخّلات من صيانةٍ تصحيحيّةٍ إلى صيانةٍ وقائيّة، بما يضمن توفّر خطوط الإنتاج وموثوقيّتها. ويُنجَز النهجُ الهجين المقترَح في شكل سلسلة معالجةٍ (Kafka، InfluxDB، Grafana، Prometheus) مع إنذاراتٍ متدرّجةٍ وخاليةٍ من التكرار، مع حلقة تعلّمٍ نشطٍ يقودها المشغّل وتُعيد تدريب النموذج. والهدف النهائيّ هو البناء التدريجيّ لذاكرةٍ مؤسّسيّةٍ تحلّ مشكلة عدم توفّر الخبراء.

الكلمات المفتاحيّة: الصيانة التنبّؤيّة، كشف الشذوذ، المحوّلات، المُرمِّز التلقائي، الاستدلال المبنيّ على الحالات، الذاكرة المؤسّسيّة، الفرن الدوّار.