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Privacy-preserving AI-based framework for container transportation demand forecasting in sea-rail intermodal systems

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ABSTRACT

In response to the growing demand for accurate freight forecasting in sea-rail intermodal transportation, particularly under the constraints of stringent data protection regulations, we introduce a privacy-preserving, AI-based framework that focuses on the micro-level identification of container transport potential. The framework combines Vertical Federated Learning (VFL) with advanced feature and sample selection techniques. It leverages privacy-preserving methods, such as homomorphic encryption and random noise, enabling secure collaboration between ports and railways while safeguarding commercially sensitive data. Through extensive experiments, our framework demonstrates superior performance in predicting container transport demand, significantly improving the accuracy of resource allocation and scheduling decisions for rail operators. The framework not only ensures compliance with data protection regulations but also provides valuable insights into intermodal transportation planning, optimizing both railway operations and customer service quality. This approach offers a practical solution for improving strategic decision-making in the sea-rail intermodal sector amid increasing privacy demands and complex logistical challenges.

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Pristop z uporabo umetne inteligence za napovedovanje povpraševanja po kontejnerskem prevozu v pomorsko-železniških intermodalnih sistemih ob varovanju podatkov

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POVZETEK

Kot odziv na vse večje potrebe po natančnem napovedovanju tovora v pomorsko-železniškem intermodalnem prometu, zlasti ob omejitvah, ki jih narekujejo strogi predpisi o varovanju podatkov, predstavljamo pristop z uporabo umetne inteligence za napovedovanje povpraševanja po kontejnerskem prevozu ob hkratnem varovanju podatkov. Pristop se osredotoča na identifikacijo kontejnerjev z možnostjo nadaljnjega železniškega prevoza na ravni posameznega kontejnerja. Združuje navpično zvezno učenje (angl. Vertical Federated Learning, VFL) z naprednimi metodami izbire učnih vzorcev in vhodnih značilk. Pri tem uporablja postopke za varovanje podatkov, kot sta homomorfno šifriranje in dodajanje naključnega šuma, kar omogoča varno sodelovanje med pristanišči in železnicami ter hkrati ščiti poslovno občutljive informacije. Rezultati obsežnih eksperimentov kažejo, da pristop dosega visoko natančnost pri napovedovanju povpraševanja po kontejnerskem prevozu ter bistveno izboljšuje zanesljivost odločitev o razporejanju virov in načrtovanju prevozov pri železniških operaterjih. Poleg tega zagotavlja skladnost s predpisi o varovanju podatkov, ponuja dragocene vpoglede v načrtovanje intermodalnega prometa ter prispeva k optimizaciji delovanja železniških sistemov in izboljšanju kakovosti storitev za uporabnike. Predlagani pristop ponuja praktično rešitev za izboljšanje strateškega odločanja v pomorsko-železniškem intermodalnem prometu ob naraščajočih zahtevah glede varovanja podatkov in vse bolj zapletenih logističnih izzivih.

PODATKI O ČLANKU

Ključne besede:
Napovedovanje povpraševanja po tovoru;
Navpično zvezno učenje;
Metode za varovanje podatkov;
Izbor učnih vzorcev in vhodnih značilk;
Strojno učenje;
Homomorfno šifriranje;
Razporejanje virov in načrtovanje prevozov

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