AUTOMATIC DETECTION AND INDICATION OF PALLET-LEVEL TAGGING FROM RFID READINGS USING MACHINE LEARNING ALGORITHMS

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SUPERVISOR'S DECLARATION

I hereby declare that I have checked this thesis and in my opinion, this thesis is adequate in terms of scope and quality for the award of the degree of Master of Science.

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STUDENT'S DECLARATION

I hereby declare that the work in this thesis is based on my original work except for quotations and citations which have been duly acknowledged. I also declare that it has not been previously or concurrently submitted for any other degree at Universiti Malaysia Pahang or any other institutions.

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ABSTRAK

Dalam menentukan lokasi atau kedudukan barang-barang yang boleh dikembalikan di dalam persekitaran yang besar seperti di dalam gudang memerlukan sistem pengesanan luas di mana ia mengenal pasti lokasi barang melalui visualisasi data. Perkara ini juga sama untuk isyarat aras palet pengecaman frekuensi Radio (RFID) kerana ketepatan kedudukan untuk lokasi tertentu ditentukan sama ada tanda RFID disusun pada aras sama atau disusun secara bertindih pada arah yang sama adalah dibaca dengan seragam. Oleh itu, pendekatan metodologi yang berupaya memberikan penyelesaian holistik adalah penting untuk mengurangkan masalah dalam mencari produk pada skala yang besar. Tesis ini menghuraikan teknik untuk menentukan aras palet tanda RFID yang disusun secara bertindih menggunakan teknik pembelajaran mesin. Pertama, aras palet ditentukan secara pengelompokan manual berdasarkan tanda nombor kod produk bagi menentukan kedudukan aras sebenar. Kajian tambahan berkenaan frekuensi radio pada kotak palet yang ditanda dalam keadaan statik telah dilakukan dengan menentukan atribut siri masa. Pelbagai ukuran sampel iaitu 1 Hz, 5 Hz dan 10 Hz digabungkan dengan kekuatan isyarat maksimum, minimum, mod, median, min, varians, perbezaan maksimum dan minimum, *kurtosis* dan *skewness* adalah dinilai. Atribut-atribut statistik dari bacaan kekuatan isyarat yang diterima kemudiannya dianalisis dengan memilih atribut-atribut univariat, menggunakan teknik atribut penting dan juga analisis komponen utama. Kekuatan isyarat yang diterima melalui atribut maksimum, median dan minimum adalah atribut-atribut statistik yang signifikan bagi saiz sampel 10 Hz. Pengelasan-pengelasan pembelajaran mesin yang berbeza telah diuji berdasarkan atribut-atribut penting, iaitu menggunakan algoritma Rangkaian Neural Buatan, Pokok Keputusan, Hutan Rawak (RFt), Mesin Vektor Sokongan, Bayes Naif dan k-Jiran Terdekat. Keputusan eksperimen menunjukkan bahawa 95.02% model RFt yang terlatih telah berjaya dikelaskan. Ini jelas menunjukkan bahawa kerangka kerja yang dibina adalah praktikal untuk mengelaskan aras palet. Tambahan pula, keberkesanan model yang berbeza berdasarkan penalaan hiper-parameter heuristik dinilai menggunakan fungsi kernel yang berlainan pada Mesin Vektor Sokongan dan pelbagai metrik ukuran jarak pada k-Jiran Terdekat. Selain itu, teknik pembelajaran berkumpulan, perubahan fungsi pengaktifan pada Rangkaian Neural Buatan serta pembelajaran tanpa pengawasan (algoritma pengelompokan *k-means* dan Persamaan Transmisi *Friis*) juga telah digunakan untuk pengelasan aras palet pelbagai-kelas. Didapati bahawa RFt memperolehi ketepatan tertinggi iaitu 92.44% pada set ujian. Ujikaji seterusnya dijalankan untuk mengesahkan kedudukan tanda kotak palet menggunakan model RFt yang dibangunkan. Lokasi kotak yang telah ditentukan sebelumnya digunakan untuk mengesahkan model ini. Kedudukan terbaik yang memperolehi ketepatan pengelasan sebanyak 93.30% melalui proses pengesahan adalah kedudukan lima (5) pada model sistematik di mana ia merupakan titik tengah kotak palet. Kesimpulannya, analisis menunjukkan bahawa RFt mempunyai prestasi ramalan terbaik berbanding model-model pembahagian aras palet yang lain dengan ketinggian yang ditetapkan sebanyak 12 sm. Berdasarkan set ujian, pengesahan dan latihan dalam model RFt, RFID berupaya untuk menentukan kedudukan palet secara tepat.

ABSTRACT

Identifying specific locations of items such as containers, warehouse pellets, and returnable packages in a large environment, for instance, in a warehouse, requires an extensive tracking system that could identify the location through data visualization. This is the similar case for radio-frequency identification (RFID) pallet level signal as the accuracy of determining the position for specific location either on the level or stacked in the same direction are read uniformly. However, there is no single study focusing on pallet-level classification, in particular on distance measurement of pallet height. Hence, a methodological approach that could provide the solution is essential to reduce the misplaced issues and thus reduce the problem in searching the products in a large-scale setting. The objective of this work attempts to define the pallet level of the stacked RFID tags through the machine learning techniques framework. The methodology started with the pallet-level which firstly determined by manual clustering according to the product code number of the tags that were manufactured for defining the actual level. An additional study of the radio frequency of the tagged pallet box in static condition was carried out by determining the feature of the time series. Various sample sizes of 1 Hz, 5 Hz and 10 Hz combined with the received signal strength of maximum, minimum, mode, median, mean, variance, maximum and minimum difference, kurtosis and skewness are evaluated. The statistical features of the received signal strength reading are analyzed by the selection of the univariate features, feature importance technique, and principal component analysis. The received signal strength of the maximum, median, and mean of all statistical features has been shown to be significant specifically for the 10Hz sample size. Different machine learning classifiers were tested based on the significant features, namely the Artificial Neural Network, Decision Tree, Random Forest, Naive Bayes Support Vector Machine, and k-Nearest Neighbors. It was shown that up to 95.02% of the trained Random Forest Model could be classified, indicating that the established framework is viable for pallet classification. Furthermore, the efficacy of different models based on heuristic hyperparameter tuning is evaluated in which the different kernel function for Support Vector Machine, various distance metrics of k-Nearest Neighbors. The ensemble learning technique, changes of activation function in Neural Network as well as the unsupervised learning (k-means clustering algorithm and Friis Transmission Equation) was also applied to classify the multiclass classification in pallet-level. In results, it was found that the Random Forest provided 92.44% of the test sets with the highest accuracy. In order to further validate the position of the tagging in the pallet box of the Random Forest model developed, a different predefined location was used to validate the model. The best position that could achieve a classification accuracy of 93.30% through the validation process for position five (5) in the systematic model that is the centre of the pallet box. In conclusion, it can be inferred from the analysis that the Random Forest model has better predictive performance compared to the rest of the pallet level partition model with a height of 12 cm used in this research. Based on the train, validation, and test sets in Random Forest, the RFID capability to determine the position of the pallet can be detected precisely.

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