論　文　要　旨
Thesis Abstract

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※報告番号	甲第３１０号	氏　名 (Name)	Kanokporn Boonjubut

主論文題名　（Title）Demand Modeling and Optimization Algorithms for Rebalancing Operations in Bike-Sharing Systems

内容の要旨　（Abstract）

The number of bike-sharing services has rapidly increased in many cities worldwide. Bike-sharing schemes have become a popular and environmentally friendly transportation mode. They are an alternative to urban transport for connecting the first/last mile to main public transport modes. The bike-sharing system is a service that allows a customer to rent a bike from a bike-sharing station and return it to another bike-sharing station after they reach their destination in a short while. Thus, the impact of the bike distribution system based on the frequency of bike usage needs to be assessed.

One of the main challenges of the bike-sharing system operating costs is allocating enough bikes and parking space. There is a shortage of bikes due to an imbalance in bike distribution. Bike-sharing systems experience an imbalance in customer demand too at each station. The operation's primary focus has been on rebalancing the bikes among stations. To avoid customer dissatisfaction, the demand-supply imbalance of the bikes in the system must be minimized. The bike-sharing system operator needs to maintain a balance between available bikes and available docking.

This study was conducted to improve the efficiency of bike-sharing systems and to predict the demand accurately so that the planner knows how many bikes are needed at every station, which will aid the management process of the bike-sharing stations. First, a method was presented for predicting the demand for bikes. This study proposed an efficient and accurate model for predicting bike-sharing service usage using various features of a machine learning algorithm. This work compared the existing techniques for the sequential data prediction of artificial intelligence for time series data and analysis. It used the multivariate model with a recurrent neural network (RNN), a long short-term memory (LSTM), and a gated recurrent unit (GRU). In addition, it considered combining the LSTM and GRU methods to improve the model's effectiveness and accuracy.

Further, this work focused on the imbalances caused by problems with insufficient bikes or docking stations in such schemes, leading to operating costs for relocating the bikes. This work presented a model for solving the bike-sharing relocation problem. Though the artificial bee colony (ABC) algorithm is an efficient approach, it is insufficient for the selection strategy. ABC has been adopted in various problems to improve the performance of various systems. This research proposed a modified ABC algorithm in a neighbor solution,

namely guided local search (GLS), to enhance the solution performance. Computational experiments were performed to find out the best modeling solution in the case. The implementations were experimental for the same data instances, which made it possible to compare the performance algorithms to solve the bike-sharing relocation problem of pick-up and drop-off.

Recent studies have proposed reinforcement learning as a computation-based learning method that yields more accurate results. This study proposed Q-learning and SARSA of reinforcement learning as a fast convergence solution to a routing problem. We implemented this by determining the distance between each station and considering the capacity of the trucks. The model of this study introduced reinforcement learning, consisting of the Q – Learning and SARSA for finding the solution. Q-Learning and SARSA produce better results than GA and ABC. Consequently, our proposal can be applied to the CVRP problem.

An analysis has been carried out in this work using data mining to determine bike activity patterns at the station and gain insights into them. The activity model revealed an imbalance in the bike distribution. The data mining process supports operating decisions of bike-sharing systems to ascertain the critical point of the system, making a resolution easier. This case study used a simulation based on the arrival rate, which assists in managing a bike-sharing rebalancing system with the most profitable objective and meeting the users' needs.

One factor that should not be overlooked is the location of the depot. Here, a method was proposed, based on cluster analysis, for considering depot location in bike-sharing schemes. The main objective is to reduce operating costs by minimizing the total distance required in relocating bikes. The WK-means and Elbow Method were used to determine the number and location of depots; thereafter, the total distance required for different depot location options was considered. The results indicate that the proposed method performs well in terms of reducing the total distance required.

The components related to the development of bike-sharing systems consist of 1) the forecast model by combining the LSTM and GRU methods to improve effectiveness and accuracy of the predicted model, 2) modified ABC Algorithm, as the GLS-ABC can be a better solution than the original one, 3) application of reinforcement learning to use in routing to achieve the shortest distance (the impact of minimizing the route tour cost in solving the bike-sharing relocation problem), 4) model for maximizing profit by simulating and 5) locating the depot by the clustering method which found the results of the changes that occurred in the system development process. The methods presented in this research not only help to improve the quality of the bike-sharing system but also serve as a foundation for the development of methodologies related to industries with similar problems.

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