Investigation of Heterogeneous Service Times in Outpatient Clinics Using Clustering and Discrete-Event Simulation

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ABSTRACT

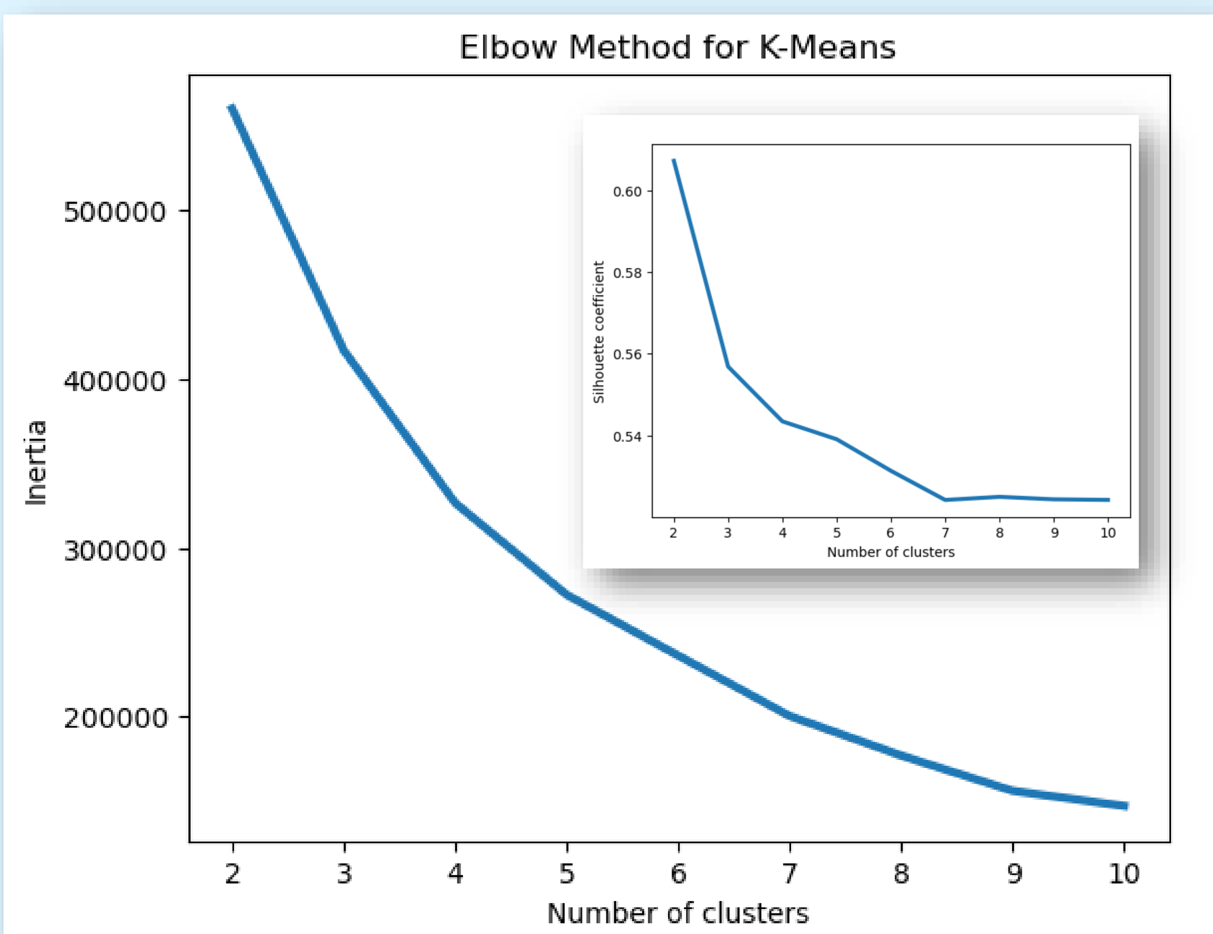
In recent years, long waiting times for healthcare services have been a major policy concern in most OECD countries, according to a 2020 OECD report [1]. This study investigates service duration patterns through clustering analysis and a fuzzy logic approach.

INTRODUCTION

Healthcare service providers often face challenges in managing patient queues, leading to longer waiting times, negative patient experience, and inefficient resource utilization. Traditional queue management approaches are often insufficient within clinical environments due to dynamic patient flow, varying service durations, and limited medical resources. This study examines outpatient appointment scheduling and queue modelling strategies in order to reduce patient waiting times and evaluate service efficiency, using the open-access Hangu clinic dataset [2]. Understanding service duration patterns is critical for resource planning and operational efficiency.

The aim of this study is to predict the average waiting time, average number in the queue, and average service duration. Also, the prototype of the system was built using Flask framework.

CLUSTERING RESULTS



Cluster A. Beta distribution (α=2.28, β=1.06, loc=168.35, scale=496.74) - **Short-duration services**

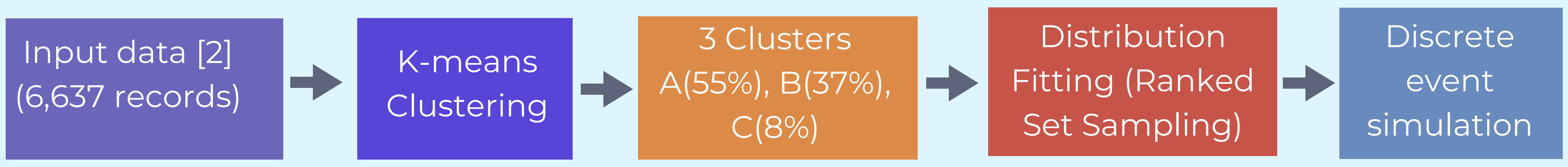
Cluster B. Beta distribution (α=0.91, β=1.11, loc=666, scale=359.34) - **Medium-duration services**

Cluster C. Pareto distribution (b=22.96, loc=-5888.76, scale=6914.76) - **Long-tail behavior**

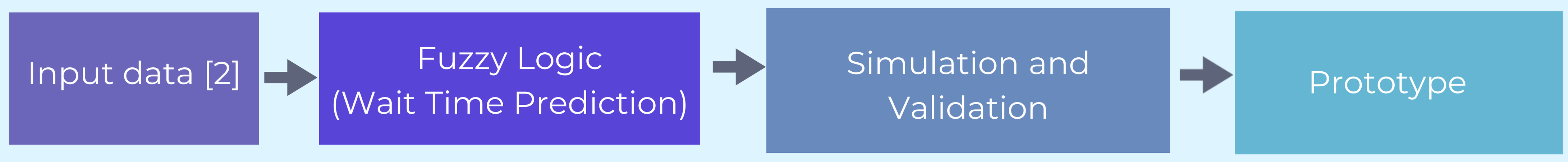
METHODOLOGY

This study analyzes the Hangu dataset [2] through two scenarios. The Hangu dataset contains service time records with heterogeneous features such as patient demographics, medical problems, and previous visit information. However, there is no information about the patient's arrival time at the clinic.

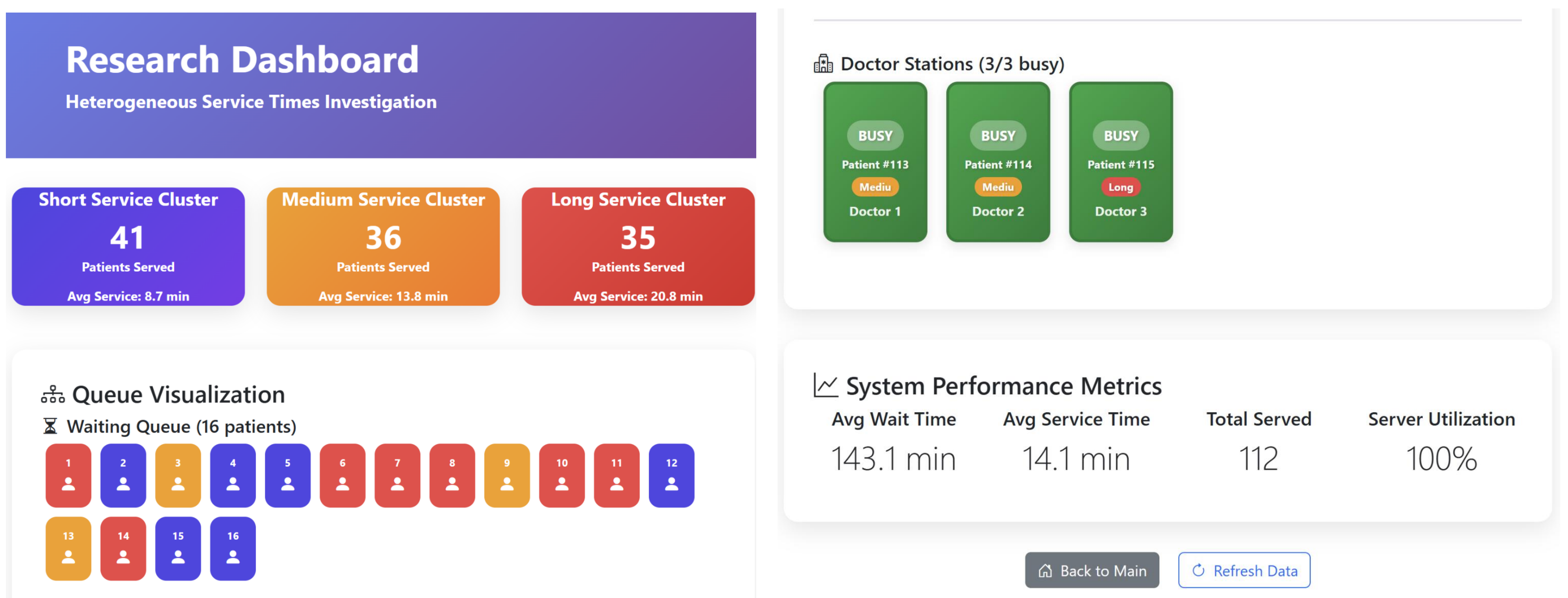
The first scenario. Clustering analysis. The optimal number of clusters was selected based on the silhouette coefficient and the elbow graph, using the k-means method [3]. Subsequently, distribution fitting was applied, and a discrete event model was developed.

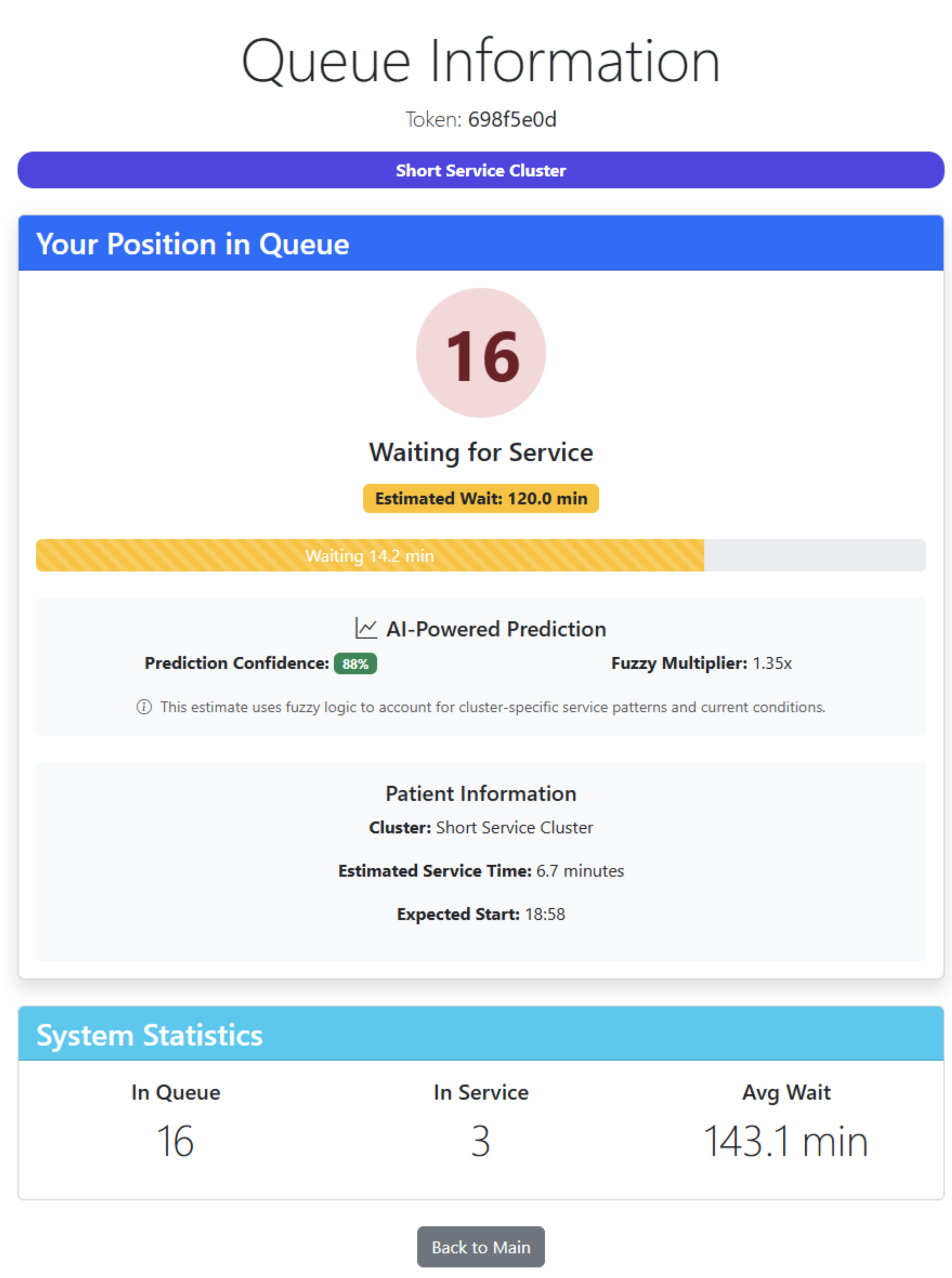


The second scenario. Fuzzy Logic System. A Mamdani-type fuzzy inference system [4] with 25 IF-THEN rules was implemented for dynamic wait time estimation, incorporating four input variables: queue length, time of day, day of week, and patient type. The system uses triangular membership functions and centroid defuzzification to produce real-time wait time predictions.



PROTOTYPE OF THE SYSTEM





CONCLUSIONS

In this investigation, two models were proposed to predict the average waiting time, average queue length, and average service duration. Both models demonstrated good agreement with real-world data. The accuracy of the model in the second scenario was 88%.

3 patient clusters with associated service durations and inter-arrival times were used as input for a discrete-event simulation to evaluate queue dynamics. The proposed model allows the prediction of different scenarios of patient flow intensities. It should be noted that the time between arrivals was used according to the Poisson distribution.

Future work includes incorporating seasonality and staff availability factors into the proposed model.

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