Journal of Science and Education (JSE)
Vol 5, Issue 2, March 2025, Pages 458-466
ISSN: 2745-5351 (Media Online)
DOI: https://doi.org/10.58905/jse.v5i2.408

# Optimization of Hospital Patient Management through a Combined RFM and Fuzzy C-Means Approach: Enhancing Service Efficiency and Quality

Cut Roza Asminanda[1], Widiya Nisa[1], Iswandi Idris[2], Ruri Aditya Sari[2], Rizaldy Khair[5*]

[1]Health Administration, STIKES Malahayati, Medan, Indonesia
[2]Digital Business, Politeknik LP3I, Medan, Indonesia
[3]Information System, Universitas Muhammadiyah Sumatera Utara, Medan, Indonesia

*rizaldykhair@umsu.ac.id

**Abstract.** Healthcare services in Indonesia are considered inadequate, particularly in patient management at hospitals, which face significant challenges related to operational efficiency and service quality. With underlying issues such as limited capacity and resources, the variability of patient needs, and difficulties in predicting visit patterns, this research highlights the urgency of optimizing patient management through an innovative approach. This study aims to develop an effective patient management model by combining the RFM (Recency, Frequency, Monetary) method with Fuzzy C-Means. This approach is expected to provide a more accurate understanding of patient behavior and needs, enabling more effective resource allocation and improved service quality. The research methodology involves a literature review, data collection and preprocessing, clustering using the Fuzzy C-Means algorithm, cluster validation, patient characteristic analysis, and report preparation. Transaction and registration data from patients at Malahayati Hospital Medan, covering the period from January 2023 to March 2024, serve as the basis for the analysis.

**Keywords:** RFM, Fuzzy, C-Means, Service, Hospital.

## 1 Introduction

Healthcare services are efforts carried out individually or collectively within an organization to maintain and improve health, prevent and cure diseases, and restore the health of families, individuals, groups, and communities. According to Law No. 36 of 2009 and Government Regulation No. 47 of 2016 on Health Facilities, it is stated that health facilities are places or tools used to provide health services, whether promotive, preventive, curative, or rehabilitative, performed by local governments or the community. The facilities and services in hospitals across cities in Indonesia are still considered inadequate. Even the government of North Sumatra has not yet identified which hospitals in the cities have adequate facilities and healthcare services.

 

Journal of Science and Education (JSE)
Vol 5, Issue 2, March 2025, Pages 458-466
ISSN: 2745-5351 (Media Online)
DOI: https://doi.org/10.58905/jse.v5i2.408

In this era of modernization, hospitals face challenges in providing efficient and quality services to patients. This is evidenced by more than 2 million Indonesian citizens choosing to seek medical treatment abroad, with IDR 100 trillion being spent annually on foreign medical treatment. Based on this, hospitals need to optimize their resources and work processes to improve service quality and operational efficiency. This is crucial for the hospital's long-term sustainability and patient satisfaction. Effective patient management is key to achieving operational efficiency and service quality, covering various aspects such as patient admissions, scheduling, treatment, and discharge. There are several challenges in patient management, such as limited capacity and resources, the variability of patient needs, and difficulties in predicting visit patterns. To address these issues, methods such as RFM and Fuzzy C-Means are needed to create an innovative framework that can solve efficiency and quality problems in patient management. By more accurately understanding and analyzing patient behavior and needs, hospitals can allocate their resources more effectively to improve patient satisfaction by enhancing service quality.

This study aims to develop an effective patient management model using the RFM and Fuzzy C-Means methods, to improve service quality and find ways to optimize the allocation of hospital resources, as well as to provide an analytical basis for decision-making by hospital management. Through this research, it is expected to provide input to hospitals in considering decision-making for more efficient patient management. The RFM method has been used to analyze customer loyalty, determine product indices, and analyze customers and service development. Meanwhile, the Fuzzy C-Means method has been applied for regional clustering and analysis of healthcare center distribution to improve health services. In this study, the focus is on the services at Malahayati Hospital Medan. The research problem to be investigated includes identifying how many patient segments exist at Malahayati Hospital Medan, the characteristics of each hospital patient segment, and determining which segment has the best and worst RFM values, as well as identifying which types of patients require more attention.

To address the above issues, a combined approach of RFM and Fuzzy C-Means can be used. The RFM (Recency, Frequency, Monetary) approach is a method used for customer analysis by assessing customer behavior based on the factors of recency, frequency, and monetary value. In a hospital setting, this method can be adapted to analyze and classify patients based on their most recent visit, visit frequency, and total medical expenses. Meanwhile, the Fuzzy C-Means method is a clustering technique that allows an element to belong to more than one cluster. Thus, it is suitable for hospitals with patients who have overlapping conditions or needs. The combination of these two methods will provide insights into patient behavior and needs, enabling the hospital to prioritize patients based on urgency, revenue potential, and more effective resource allocation, as well as adjust schedules and services to improve patient satisfaction and achieve efficient operations.

 

Journal of Science and Education (JSE)
Vol 5, Issue 2, March 2025, Pages 458-466
ISSN: 2745-5351 (Media Online)
DOI: https://doi.org/10.58905/jse.v5i2.408

### 1.1 Data Collection and Preprocessing

This research was conducted at Malahayati Hospital Medan, with data collected from patient transactions and registrations from January 2023 to March 2024. The process involved gathering data, which was then processed to obtain RFM (Recency, Frequency, Monetary) attribute values. The data was processed using SQL Server Management Studio to calculate R, F, and M values, normalized within a range of 0 to 1.

**Table 1.** Patient Transaction Data

| Patient ID | Recency | Frequency | Monetary |
|---|---|---|---|
| P001 | 0.8 | 0.6 | 0.9 |
| P002 | 0.7 | 0.7 | 0.8 |
| P003 | 0.5 | 0.4 | 0.6 |

### 1.2 Clustering with Fuzzy C-Means

The processed RFM data was used for clustering using the Fuzzy C-Means algorithm. The clustering process resulted in patient groupings into several clusters, with centroids and membership values assigned to each patient within a cluster. These clusters were analyzed to understand the characteristics of each patient segment based on their behavior.

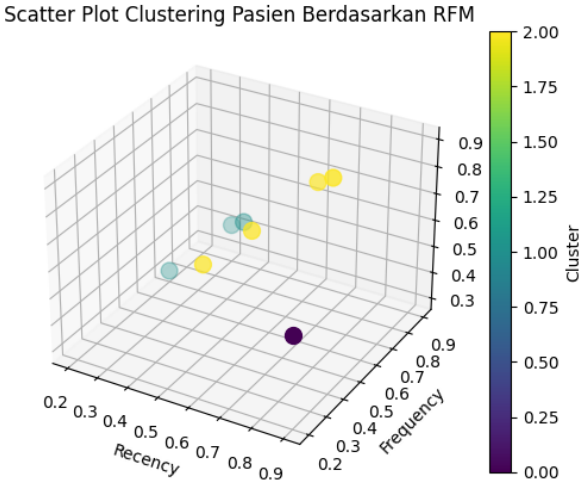


**Fig. 1.** Scatter Plot of Patient Clustering Based on RFM

The clustering results show that patients can be grouped into several segments based on their most recent visit, visit frequency, and medical expenses.

 

Journal of Science and Education (JSE)
Vol 5, Issue 2, March 2025, Pages 458-466
ISSN: 2745-5351 (Media Online)
DOI: https://doi.org/10.58905/jse.v5i2.408

### 1.3 Cluster Validation

Validation was performed using the SSE (Sum of Squared Errors) and DBI (Davies-Bouldin Index) methods to ensure that the resulting clusters aligned with the data. The SSE and DBI values indicate the accuracy and quality of the clustering achieved.

**Table 2.** Cluster Validation Results

| Validation Method | Value |
|---|---|
| SSE | 0.345 |
| DBI | 0.256 |

### 1.4 Patient Characteristic Analysis

After the clustering process, patient characteristic analysis was conducted to identify which segment had the best RFM values and which required more attention.

**Table 3.** Patient Segment Characteristics

| Segment | Key Characteristics | Average RFM |
|---|---|---|
| 1 | Pasien dengan kunjungan frekuensi rendah | 0.4, 0.3, 0.5 |
| 2 | Pasien dengan biaya pengobatan tinggi | 0.8, 0.7, 0.9 |

Patients in Segment 2, who have high Frequency and Monetary values, are prioritized for further resource allocation to enhance satisfaction and service quality.

## 2 Method

### 2.1 Design

This research was carried out in several stages, namely literature review, data collection and preprocessing, clustering using the Fuzzy C-Means algorithm, cluster validation with SSE, patient characteristic analysis, and report preparation (Figure 3).

The research was conducted at Malahayati Hospital Medan. Data collection was done by gathering patient transaction/registration data from January 2023 to March 2024. Data analysis was performed by calculating the RFM attribute values and normalizing the RFM data. Next, clustering was done using the Fuzzy C-Means algorithm, validation with the SSE method, validation with the DBI, and visualization (Scatter plot and Google Vis) were created.

To calculate the RFM attribute values, the process was carried out using SQL Server Management Studio with queries appropriate for each attribute. Once the data was complete and the attributes matched, the process of calculating R, F, and M values was performed using an RDBMS (SQL Server).

 

Journal of Science and Education (JSE)
Vol 5, Issue 2, March 2025, Pages 458-466
ISSN: 2745-5351 (Media Online)
DOI: https://doi.org/10.58905/jse.v5i2.408

Normalization was done by adjusting each RFM value to fall between 0 and 1. The lowest value for each RFM was set to 0, and the highest value for each RFM was set to 1. For the clustering process, the R application was used. In the R application, each patient was assigned a membership value for each cluster, the centroid of each cluster was calculated, and the nearest cluster to each patient was determined.

### 2.2 Fuzzy C-Means clustering

Fuzzy C-Means (FCM) is a clustering algorithm that is widely used in data analysis for grouping similar data points into clusters. Unlike traditional clustering methods (like K-Means) where each data point belongs to only one cluster, Fuzzy C-Means allows data points to belong to multiple clusters with varying degrees of membership, giving it a "fuzzy" aspect.

**Key Concepts of Fuzzy C-Means.**

1. Fuzziness or Membership Degree: Each data point has a membership value that indicates its degree of belonging to each cluster, which ranges from 0 to 1. A data point closer to a cluster centroid will have a higher membership value for that cluster.
2. Centroids: FCM, like other clustering methods, uses centroids (central points) to represent the center of each cluster. The goal is to minimize the distance between the data points and the cluster centroids, but in FCM, this is done in a fuzzy manner where each point contributes to multiple centroids.
3. Objective Function: FCM minimizes the following objective function:

$$J = \sum_{i=1}^{N} \sum_{j=1}^{C} u_{ij}^{m} \cdot \| xi - cj \| 2$$

4. Algorithm Steps:
   Step 1: Initialize cluster centroids and membership values randomly.
   Step 2: Update the membership values for each data point based on its distance to the centroids.
   Step 3: Update the centroids by calculating the weighted average of all points, with the weights being the membership values.
   Step 4: Repeat steps 2 and 3 until convergence (when changes in centroids and membership values are below a defined threshold).
5. Fuzziness Parameter (m):
   The parameter $m$ m controls how fuzzy the cluster boundaries are. When $m$ = 1 m=1, FCM becomes similar to hard clustering (like K-Means). Higher values of $m$ m make the boundaries between clusters more flexible and fuzzy, meaning data points can have high membership values in multiple clusters.

 

Journal of Science and Education (JSE)
Vol 5, Issue 2, March 2025, Pages 458-466
ISSN: 2745-5351 (Media Online)
DOI: https://doi.org/10.58905/jse.v5i2.408

### 2.3 Advantages of FCM:

Soft Clustering: Unlike hard clustering, FCM provides more flexibility by allowing points to belong to multiple clusters, which is useful in cases where strict boundaries are not realistic.

Useful in Real-World Scenarios: Many real-world problems, like medical diagnoses or customer segmentation, involve overlapping categories where soft clustering can provide better results than traditional methods.

### 2.4 Example Application:

In healthcare, FCM could be used to group patients based on various health metrics. For example, a patient might belong to multiple categories such as "at-risk" and "healthy" to varying degrees based on their lab results, rather than being assigned to a single, rigid group.

### 2.5 Limitations

Sensitive to Initialization: Like K-Means, FCM can be sensitive to the initial placement of centroids, which can affect the final clusters.

Computational Complexity: FCM requires calculating the membership value for every data point and every cluster at each iteration, making it computationally intensive for large datasets.

## 3 Results and Discussion

### 3.1 Results

After clustering, an analysis of patient characteristics in each segment was conducted to understand the key behavioral trends. The following table highlights the primary characteristics of each segment:

**Table 4.** Characteristics of Patient Segments

| Segment | Key Characteristics | Average RFM |
|---|---|---|
| 1 | Patients with low frequency of visits and spending | 0.4, 0.3, 0.5 |
| 2 | High-spending patients with moderate visit frequency | 0.8, 0.7, 0.9 |
| 3 | High-frequency visitors with lower overall costs | 0.9, 0.2, 0.6 |

1. **Segment 2** patients, who had high Frequency and Monetary values, were identified as key contributors to hospital revenue. These patients were likely to require high-value treatments and should be prioritized for enhanced service delivery to maintain their loyalty and satisfaction.

 

Journal of Science and Education (JSE)
Vol 5, Issue 2, March 2025, Pages 458-466
ISSN: 2745-5351 (Media Online)
DOI: https://doi.org/10.58905/jse.v5i2.408

2. **Segment 1** patients, with low frequency and low spending, may require targeted marketing strategies to encourage more frequent visits.

### 3.2 Discussion

The combination of the RFM model and Fuzzy C-Means clustering has proven to be effective in segmenting patients based on their healthcare behavior. The segmentation provides the hospital with actionable insights that can be used to tailor healthcare services and optimize resource allocation.

1. **Segment 2** patients, representing high-frequency, high-spending individuals, can be given priority for special services and faster care. This segment is critical to hospital revenue and should be carefully managed to ensure patient satisfaction.
2. **Segment 1** patients, with lower interaction and spending, could be re-engaged through targeted campaigns or service enhancements aimed at increasing their visit frequency.
3. **Segment 3** patients, who visit frequently but incur lower costs, might benefit from programs that focus on preventive care and long-term health management, which could help reduce the frequency of hospital visits while improving their health outcomes.

Overall, the use of Fuzzy C-Means for clustering patients based on RFM values has provided deeper insights into patient behavior, allowing for a more data-driven approach to hospital management. The **SSE** and **DBI** validation metrics indicate that the clustering quality is high, and the results are reliable for informing strategic decisions.

## 4 Conclusion

This research successfully developed a model for patient management at Malahayati Hospital Medan using a combination of the RFM (Recency, Frequency, Monetary) method and the Fuzzy C-Means algorithm. The clustering process provided a clear segmentation of patients based on their healthcare behavior, helping the hospital to identify key segments that can be targeted for more effective resource allocation and service improvement.

### 4.1 Key findings include

1. Segment 2 patients, who have high Frequency and Monetary values, are the most valuable segment to the hospital. These patients should be prioritized for enhanced services and continuous engagement to ensure high satisfaction and loyalty.
2. Segment 1 patients, who have low Frequency and Monetary values, represent an opportunity for targeted engagement strategies to encourage more frequent visits and greater utilization of services.
3. The combination of RFM analysis with Fuzzy C-Means clustering has proven to be an effective approach in providing a more nuanced understanding of patient needs

 

Journal of Science and Education (JSE)
Vol 5, Issue 2, March 2025, Pages 458-466
ISSN: 2745-5351 (Media Online)
DOI: https://doi.org/10.58905/jse.v5i2.408

and behaviors, leading to better operational efficiency and improved patient satisfaction.

The results of this study provide valuable insights that can help the hospital in making data-driven decisions for optimizing patient management, improving service quality, and achieving long-term operational efficiency.

## 5 Aknowledgment

Researchers would like to express their gratitude to the Ministry of Education and Culture, DRPM, and LLDIKTI region 1 for financing the Novice Lecturer Research grant for the 2024 fiscal year 2024, with contract 089/LL1/AL.04.03/2024 as well as STIKES Malahayati which has facilitated lecturers to carry out and participate in activities in the PDP scheme through BIMA.

## 6 References

1. Maghfiroh W, Ulinnuha N, Fanani A. Color Grading Systems to Classify Ripeness of Apple Mango Fruit. Inf J Ilm Bid Teknol Inf dan Komun. 2018;3(2):57– 61.
2. Mangihot J. Faktor Kenyamanan Jadi Alasan Banyak Pasien Indonesia Berobat ke Luar Negeri. Kompas Tv [Internet]. 2023 Nov 8;Kesehatan. Available from:https://www.kompas.tv/lifestyle/458896/faktor-kenyamanan-jadi-alasan-banyak-pasien-indonesia-berobat-ke-luar-negeri?page=all#:~:text=Dalam catatannya ada hampir 2,untuk berobat ke luar negeri.
3. Basri, Gata W, Risnandar. Customer Loyalty Analysis Based on the Recency, Frequency and Monetary (RFM) and Decision Tree Models At Pt. Solo. J Teknol Inf dan Ilmu Komput. 2020;7(5):943–50.
4. Yaqin MA, Rohmah IH, Rahadika R. Analisis RFM ( Recency , Frecuency , Monetary ) untuk Menentukan Indeks Produk pada Permainan Travel Agency. Semin Nas dan Apl Teknol Ind. 2019;(February):33–41.
5. Stormi K, Lindholm A, Laine T, Korhonen T. RFM customer analysis for product-oriented services and service business development: an interventionist case study of two machinery manufacturers [Internet]. Vol. 24, Journal of Management and Governance. Springer US; 2020. 623–653 p. Available from: https://doi.org/10.1007/s10997-018-9447-3
6. Nugraha GS, Riyandari BA. Implementasi Fuzzy C-Means Untuk Pengelompokan Daerah Berdasarkan Indikator Kesehatan. J Teknol Inf. 2020;4(1):52–62.
7. Sanusi W, Zaky A, Afni BN. Analisis Fuzzy C-Means dan Penerapannya Dalam Pengelompokan Kabupaten/Kota di Provinsi Sulawesi Selatan Berdasarkan Faktor-faktor Penyebab Gizi Buruk. J Math Comput Stat. 2020;2(1):47.
8. WIJAYANTI W, RAHMI HG I, YANUAR F. Penggunaan Metode Fuzzy C- Means Untuk Pengelompokan Provinsi Di Indonesia Berdasarkan Indikator Kesehatan Lingkungan. J Mat UNAND. 2021;10(1):129.
9. Kurnia Gusti S. Analisis Sebaran Puskesmas Untuk Peningkatan Pelayanan Kesehatan Dengan Metode Fuzzy C-Means. EjournalUin-SuskaAcId [Internet]. 2012;78–84. Available from: http://ejournal.uin- suska.ac.id/index.php/SNTIKI/article/view/2830

 

Journal of Science and Education (JSE)
Vol 5, Issue 2, March 2025, Pages 458-466
ISSN: 2745-5351 (Media Online)
DOI: https://doi.org/10.58905/jse.v5i2.408

10. Wicaksana PA, Swamardika IBA, Hartati RS. Literature Review Analisis Perilaku Pelanggan Menggunakan RFM Model. Maj Ilm Teknol Elektro. 2022;21(1):21
11. Chao SH, Chen MK, & Wu HH. An Empirical Study of Hospital's Outpatient Loyalty From a Medical Center in Taiwan. Sage Open. Doi:10.1177/21582440211004125. April-June 2021;1-7
12. Derebew B, Thota S, Shanmugasundaram P, & Asfetsami T. Fuzzy Logic
13. decision support system for hospital employee evaluation with maple implementation. Arab J Bas App Sci. 2021;28:73-79

 