



Original Research Paper

Machine Learning Classification of Seasonal Feeding Strategies in Urban Macaques

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Abstract

Urbanization has been recognized as an ecological factor impacting the behaviour of wildlife by transforming natural habitats, resource availability, and interaction of species. Feeding behaviors of urban macaques have been observed to be continuously impacted by environmental changes and thus, impact the feeding habits of the monkeys. Seasonal variations play a role in shaping the food availability, vegetation, and human-associated foods and thus, shape the feeding behavior of the macaques. Seasonal feeding strategies of the macaques can be useful in understanding the adaptability and effectiveness of urban wildlife management strategies. This research focus on the development of a machine learning-based approach for the automated classification of feeding behaviors in urban macaques in varying seasonal settings. This research aims to incorporate behavioral observation of the macaques along with the use of ecological features to identify and classify the feeding strategies of macaques in various seasons. Data preprocessing techniques are used to prepare the data while feature extraction techniques are used to extract important features. The suggested framework addresses the limitations of the conventional approaches to manual observation, such as the dependency on the observer, time limits, and limited observation capabilities. The classification system allows conducting a quick analysis of the big behavioral datasets and gaining better insight into the adaptation of the macaques in the urban environment. The findings have proved the applicability of machine learning algorithms in the classification of the seasonal feeding behavior and identification of behavioral patterns depending on the environmental changes.

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Introduction

Influence of Urbanization on Macaque Feeding Behaviour

There has been transformation in natural habitats through changes in vegetation structure, food availability, and resource availability in the ecosystem due to urbanization (Jaman & Huffman, 2013; Singh & Bhatnagar, 2026). There is seasonal variation in the behavior of macaques as far as feeding is concerned and how that impacts resource availability and preferences (Enari & Sakamaki-Enari, 2013; Wang et al., 2025). It gives an insight on behavioral adaptation in the changing urban environments (Stark et al., 2019).

Challenges in Traditional Feeding Behaviour Monitoring

Conventional approaches in studying the feeding behavior of animals are largely based on observations made in the field, as well as through manual recording of behavioral data. Such techniques are labor-intensive, time-consuming, and are subject to observer biases and environment (Jaman and Huffman 2013; Zhou et al., 2022). Thus, automated techniques are needed in order to analyze big behavioral data efficiently and precisely (Kiran et al., 2025; Paulet et al., 2024).

Role of Machine Learning in Animal Behaviour Classification

Techniques in machine learning can be used to solve problems in automated animal behavior analysis by identifying key features and patterns (Kiran et al., 2025; Paulet et al., 2024). This

technology can help classify animal behavior, understand feeding patterns, and enhance ecological studies (Paulet et al., 2024; Veit, 2026). The use of machine learning in such studies enables fast and accurate analysis when compared to traditional observation-based studies (Kiran et al., 2025).

Research Motivation and Objectives

Feeding behaviour of the macaques in cities needs to be effectively analysed in order to understand the effects of changing environments on their feeding patterns. The goal of this research is to construct a classification system that uses machine learning techniques to classify the feeding patterns of urban macaques.

Review of Literature

Seasonal Effects on Urban Primate Feeding Strategies

The effect of seasonality is significant when it comes to primate feeding behavior, since it affects the availability of food, food distribution, and habitats (Enari and Sakamaki-Enari, 2013; Zhou et al., 2022). Urban macaques adjust their preferences and methods of searching for food depending on the seasonality of natural and human-made food sources (Jaman and Huffman 2013; Wang et al., 2025). Such adaptations allow macaques to survive by effectively using food resources despite the changed environment (Richard et al., 1989; Stark et al., 2019).

Machine Learning Applications in Wildlife Behaviour Analysis

Machine learning methods have become increasingly significant in the study of wildlife as

they help automate the processes of recognizing and studying animals' behavior (Kiran et al., 2025; Paulet et al., 2024). They facilitate activity recognition, behavioral pattern recognition, and large-scale ecological monitoring (Paulet et al., 2024). Data-based methods save time and offer efficient ways to work with large wildlife behavior datasets (Kiran et al., 2025; Veit, 2026).

Existing Approaches for Feeding Behaviour Classification

Current approaches for categorization of feeding behavior mostly depend upon the direct observation approach, survey method, and image analysis technique (Jaman and Huffman 2013; Singh and Bhatnagar, 2026). Modern techniques utilize feature selection and machine learning techniques to detect feeding behaviors from ecological data (Kiran et al., 2025; Paulet et al., 2024). Such approaches enhance the accuracy of classification and automate the detection of feeding behaviors under different environmental situations (Paulet et al., 2024; Wang et al., 2025).

Research Gaps

Though the existing research has analyzed the behavior monitoring of animals and classification using machine learning algorithms, the automated classification of season-based feeding behavior of urban macaques is not well-established yet. The current methods lack efficient mechanisms to deal with the variability in behavior and environment. Hence, an efficient machine learning-based algorithm is needed for classification of urban macaque feeding behavior.

Methodology

Dataset Collection and Behaviour Annotation

The framework suggested uses the urban macaque feeding behavior data collected under varying seasonal conditions for the analysis of differences in their feeding behavior. The dataset contains data on their feeding behavior, resource use, and environmental data. The behaviors observed are divided into various classes and labeled accordingly to facilitate supervised classification machine learning.

Data Pre-processing and Feature Extraction

The behavioral data set obtained is first pre-processed to eliminate any discrepancies, noise, and improve the quality of data. The data set is normalized to achieve consistency among features. The important features related to the feeding process such as feeding time, food type, activity time, seasonality, and environmental features are selected for classification.

Machine Learning Classification Framework

This learning paradigm for machines is capable of categorizing feeding behavior in different seasons through behavioral features. The data input is fed into the classifier algorithms for learning and testing purposes. The learning paradigm is made up of four components namely, Data Input, Feature Processing, Learning of Model and Feeding Behavior Prediction. The trained model categorizes seasonal feeding behaviors.

Model Training and Performance Optimization

Classification models are developed by training the models on appropriate behavioral datasets. Optimal tuning of hyperparameters is done to enhance the precision and generalization of the models. Performance optimization techniques are used to minimize classification errors. An optimal framework facilitates efficient detection of feeding adaptability during seasons among urban macaques.

Results and Discussion

Classification Performance Analysis

Evaluation of the performance of the machine learning models was done based on their effectiveness in classifying seasonal feeding behavior of the urban macaques. Various classification techniques were used; whereby behavioral and ecological variables were obtained from the data set. It can be seen from the outcomes that machine learning models are

effective in recognizing feeding behavior and distinguishing seasonal changes in the behavior.

Seasonal Feeding Pattern Identification

The new framework has been successful in determining the variations in the feeding behavior of macaques during various seasons. Changes in seasons affected the availability of food resources, dietary choices, and feeding behavior patterns. When the food resources were abundant, there was an increase in the use of natural food resources by the macaques, while the scarcity of food resources led to the use of other food sources.

Model Evaluation Metrics

Performance evaluation of the classification models that were built was carried out through the use of the accuracy, precision, recall, and F1-score metrics. Accuracy is used to denote the effectiveness of feeding behavior classification, while precision and recall metrics help to understand the reliability of the detected classes of behavior. The F1-score is a comprehensive metric based on precision and recall values.

Table 1: Performance Comparison of Machine Learning Models

Model	Accuracy (%)	Precision (%)	Recall (%)	F1-score (%)
Decision Tree	88.4	86.9	87.5	87.2
Support Vector Machine	91.2	90.5	90.8	90.6
Random Forest	94.6	93.8	94.1	93.9
Neural Network	96.1	95.4	95.7	95.5

Performance analysis of various machine learning algorithms for classification of seasonal feeding behavior is illustrated in table 1. Different evaluation measures have been used for assessing performance of the algorithms

including accuracy, precision, recall and F1-Score. The results indicate that Neural Network algorithm has highest performance followed by Random Forest, Support Vector Machine and Decision Tree algorithms.

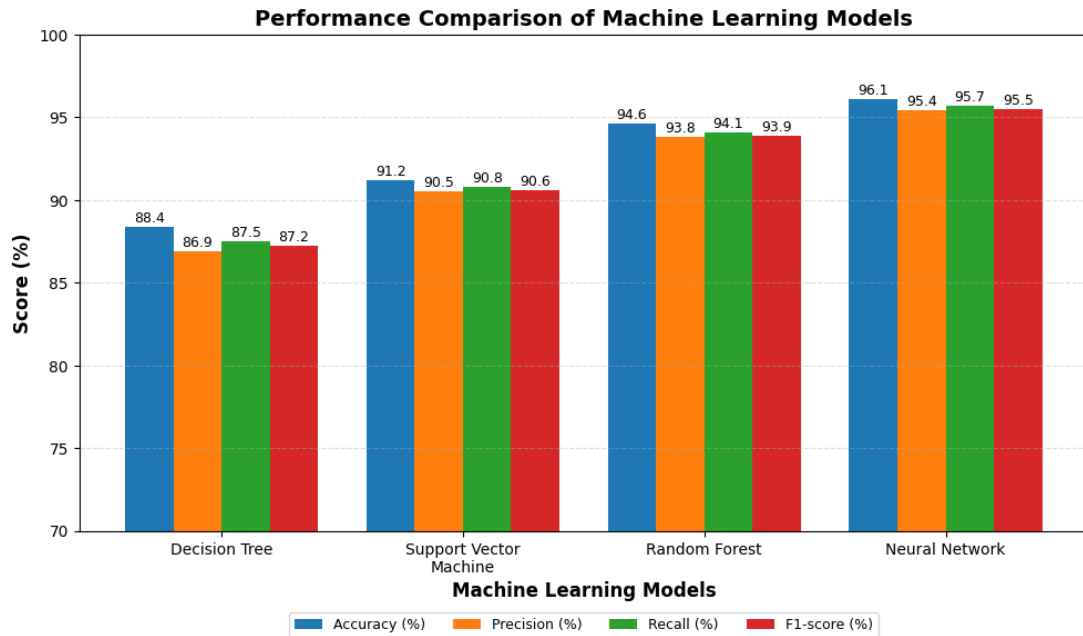


Figure 1: Performance Comparison of Machine Learning Models for Seasonal Feeding Behaviour Classification

Figure 1 shows the comparison of the performance of various machine learning models based on accuracy, precision, recall, and F1 score. It is evident from the results that the best classification performance was achieved by Neural Network, followed by Random Forest, SVM, and Decision Tree models for classifying the feeding strategy of urban macaques.

Conclusion

The current study has introduced a machine learning-based system for classification of seasonal feeding strategies of urban macaques based on behavioral and ecological factors. The introduced system minimizes the disadvantages associated with manual observations since it is capable of automated and efficient analysis of large-scale behavioral data. The experimental results have shown that machine learning systems are able to classify feeding strategies and seasonal differences in resource consumption. As

it has been mentioned above, the best performance was shown by Neural Network which has obtained 96.1% accuracy, 95.4% precision, 95.7% recall and 95.5% F1-score which exceeds other methods such as Random Forest, Support Vector Machine and Decision Tree.

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