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Abstract:

Ensuring genetic improvement of dairy cattle is essential to increase milk production and sustainability of the livestock industry. Efforts to improve the native breed are made through projects like Rashtriya Gokul Mission in India, however, methods of animal type classification, progeny testing, and pedigree selection like manual scorekeeping, record-keeping, and field testing, respectively, are time-consuming and unreliable. In addition, farmers and stakeholders who are involved in livestock rearing often find these tasks hard and cumbersome. Hence, this paper proposes an AI-powered web application called 'Smart ATC-AI System' to ease these processes and make them more efficient. This solution will allow farmers and vets to upload photographs of the animals, enter the necessary information, get evaluation results in the form of scores, and breeding recommendations. Moreover, a multilingual voice-based chatbot will be included in the system to provide guidance for users in English, Hindi, and Marathi languages. Consistent and reliable results obtained in accordance with existing ATC criteria are provided by the system. The proposed solution allows for minimizing the involvement of experts and simplifying access to the service.

Keywords:
Animal Type Classification, Progeny Testing, Pedigree Selection, Dairy Cattle, Artificial Intelligence, Smart Farming, Precision Livestock

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1. INTRODUCTION

India is a major contributor to the world's milk production with several indigenous cattle breeds. Nevertheless, despite being at a fairly high level of achievement in this regard, the genetic potential of most cattle breeds in India remains underutilized since these breeds have much higher yields in terms of their milk production.

The main reason for that stems from the insufficient application of the scientific methods of cattle breeding, like Animal Type Classification (ATC), Progeny Testing (PT), and Pedigree Selection (PS), which are known to greatly improve the quality of

domesticated cattle breeds. Nevertheless, these technologies are used only within the scope of well-established farms and governmental programs.
This problem is especially prevalent among the majority of small farmers in India that make up the foundation of the country's dairy industry because of:

• The lack of experts and experienced personnel;
• Insufficient accounting and information gathering systems;
• The lack of technological literacy and understanding of modern livestock breeding practices;
• Other geographic and financial limitations.

However, thanks to the prevalence of the smartphone use and internet access, there now exists an opportunity to address this issue with innovative software solutions like Smart ATC-AI.

2. LITERATURE REVIEW

A. *Animal Type Classification (ATC)*

Animal Type Classification (ATC), also called linear or conformation scoring, is a generally recognized system for assessing the physical characteristics of dairy livestock. ATC is predicated on the assumption that the form of the animal body correlates with its productivity and reproductive efficiency as well as its lifespan.
Typically, in the classical approach to the application of the system, expert assessors assign a score, generally between one and nine, to specific physical traits, including stature, body depth, chest width, rump angle, udder development, and proper placement of the legs. The listed traits are more than merely aesthetical: thus, an attached udder prevents mastitis, while strong legs promote longevity.
Various scientific studies indicate the positive relation of ATC traits and productivity in terms of milk output. As was demonstrated by Singh et al. (2018), the conformation features of Sahiwal cattle are strongly correlated with their total lifetime milk yield.
Nevertheless, the most significant challenge with ATC is the involvement of an expert human scorer. In rural settings, such as in India, where the majority of farmers own small holdings, finding trained ATC scorers is very difficult, leading to animals not being assessed.
Recent studies have examined the application of computer vision and image processing tools to address these challenges. For example, Salau et al. (2014) developed 3D image systems to calculate body condition scores of dairy cattle with high levels of accuracy. Likewise, Gjergji et al. (2020) found that deep learning models can predict the weight and condition of animals from simple 2D images.
From the above, it becomes evident how automation technology could replace human assessments. However, high-end imaging equipment might be too costly for rural settings. In such cases, image-based models like the Smart ATC-AI system become the best alternative.
accessibility.

B. *Progeny Testing (PT)*

Progeny Testing is believed to be among the best scientifically proven methods of assessing the genetic potential of breeding bulls. In contrast with the ATC method, which depends upon phenotypic characteristics, PT is based on the performance indicators, i.e., the milk productivity of daughters.
The rationale behind this testing method is rather simple – if the bulls' daughters have high milk yields, then their bulls should have good genetic characteristics as well. These characteristics are calculated according to statistical measures, such as the Estimated Breeding Value (EBV) that takes into account environmental factors.
The PT method is widely used in the organized dairy industry to identify bulls that can be used in artificial insemination programs. However, conducting this test may require prolonged observations as well as detailed recording of information in different locations where the daughter is raised.

In the case of India, PT exercises are carried out by institutions like the National Dairy Development Board (NDDB) and BAIF Development Research Foundation. Though the efforts have led to remarkable results in genetic improvement, the scope has been relatively narrow. As per the findings

by Menon et al. (2016), only a fraction of breeding bulls in India are subjected to formal PT.

The main hurdles involve:
• High costs and extensive resources needed
• Lack of appropriate recording of data
• Few numbers of farmers participating in the exercise
• Time-consuming process

With the advent of technology, there are prospects for the decentralization of PT exercises. The use of mobile and internet-based applications will help farmers enter the milk yield information and be part of large databases. It will make the process easier as well as improve the accuracy of genetic evaluations. The Smart ATC-AI system makes the same possible by allowing users to feed in the records of daughters' milk production and calculate PT scores instantly.

C. Pedigree Selection (PS)

Pedigree Selection is yet another significant technique in livestock breeding that estimates the genetic merit of an animal. Contrary to PT that is based on the results achieved by offspring, PS involves studying historical performance of an animal's ancestors.
The technique is grounded in the laws of quantitative genetics stating that traits are transmitted from one generation to another. The productivity of an animal can be estimated by assessing milk yield reports of its dam and maternal granddam. This technique is especially helpful when predicting future performance of young immature animals that are too young for production. It enables breeders to take timely action about mating or slaughtering.
Recent studies show that giving different levels of importance to the performance of ancestors increases the predictive power. In this case, higher priority should be given to the mother since she has greater genetic impact on offspring.
This approach is well-established in the field of breeding. At the same time, the efficacy of pedigree selection is greatly influenced by the accuracy and availability of historical data. Unfortunately, there is lack of data in many rural communities that makes the technique less useful in practice.
Such systems can resolve this problem through keeping pedigree data on record over time. The Smart ATC-AI System includes a straightforward pedigree evaluation algorithm where one can enter basic information to obtain valuable results without having to do difficult calculations.

D. Integration of Artificial Intelligence in Livestock Management

Artificial intelligence and digital technology have brought about the concept of precision livestock farming. Such an approach implies using data, sensors, and automation in agricultural production.
In highly industrialized countries, such sophisticated systems are being used to measure:
• Milk production;
• Behavior during feeding;
• Activity of animals;
• Health status;

These instruments allow for making decisions on time and diagnosing problems early enough. However, in most cases, the use of specialized hardware and software requires significant investments which cannot be afforded by small-scale farms in the developing world.
On the contrary, inexpensive digital means such as mobile and web applications have become quite popular in recent years. Such tools can be used to access services and apps directly from smartphones.
According to the study conducted by Kamilaris and Prenafeta-Boldú (2018), AI and especially deep learning technologies are gaining increasing importance in agricultural applications. It was concluded that while algorithms should be accurate.
Adoption factors include but are not limited to:
•Usability
•Language support
•Offline availability
•Payment flexibility

These aspects are considered when designing the Smart ATC-AI System. The system does not require complex and expensive technology but rather

utilizes a straightforward system that is easily usable with basic smartphones. Furthermore, the addition of a multilingual voice-enabled chatbot improves the ease of using the platform by providing an intuitive interface for users natural and intuitive way.

E. Research Gap and Motivation

Even with the presence of different methods like ATC, PT, and PS, there remains an important research gap regarding their integration and accessibility. The existing platforms focus only on one particular evaluation technique and tend to be confined to institutional use.

It is important to design a platform that:

- Harmonizes different evaluation techniques
- Is easily accessible by small-scale farmers
- Does not require high technical know-how
- Generates real-time results and recommendations

The Smart ATC-AI System fills this important research gap by bringing together different techniques and harmonizing them in a single web application.

2. SYSTEM ARCHITECTURE

A. Design Philosophy

The philosophy behind the Smart ATC-AI System design is heavily focused on practicality. There are three key elements:

- Accessibility: The design needs to be usable by farmers even without any computer skills.
- Accuracy: The results need to be accurate and scientific in nature.
- Actionability: It should produce actionable recommendations instead of a raw number score.

B. System Components

There are three major parts to this system:

1. Frontend interface

Allows users to upload data and view results.

2.Backend engine

Processes data, performs calculations and communicates with an external API.

3.Databases

Contains animal record and other necessary information.

C. Tech Stack

- Frontend: React, Tailwind CSS
- Backend: Node.js, Express
- Database: PostgreSQL
- API: Open API 3.1
- Voice Input: Web Speech API

D. Workflow

1. Uploading animal image
2. Breeding data entry
3. Data processing
4. Outputting results

3. METHODOLOGY

A. Image-Based Measurement Estimation

Based on the provided animal images, several vital measurements can be estimated:

- Wither height
- Body length
- Chest width

Applying breed-specific calibration factor allows to obtain a reasonably realistic measurement. Although the estimation is not 100% precise, it serves as an alternative to actual measurements.

B. Scoring Process

All the physical attributes receive a normalized value from 1 to 9. Final ATC score equals the average of these values.

Grading System:

- Excellent (≥7)
- Good (≥5)
- Average (<5)

C. Pedigree Scoring Model

Pedigree score is determined based on a weighted average with the following weighting:

- 65% weight to mother
- 35% weight to grandmother

D. Progeny Testing Algorithm

Based on the predetermined ranges, the system determines the mean milk yield of the daughter of

that bull and generates a score. It is the indicator of genetic merit of the breeding bull.

E. Final Scoring Model

Two final scoring models are used, which include:
• ATC + PS + PT (with PT)
• ATC + PS (without PT)
The system calculates a final score and makes suggestions, including whether an animal is:
• Recommended for breeding
• Performance should be monitored
• Not recommended

F. Chatbot Implementation

The chatbot was developed to help users resolve typical issues with a specific domain knowledge, voice support, and multilingual abilities:

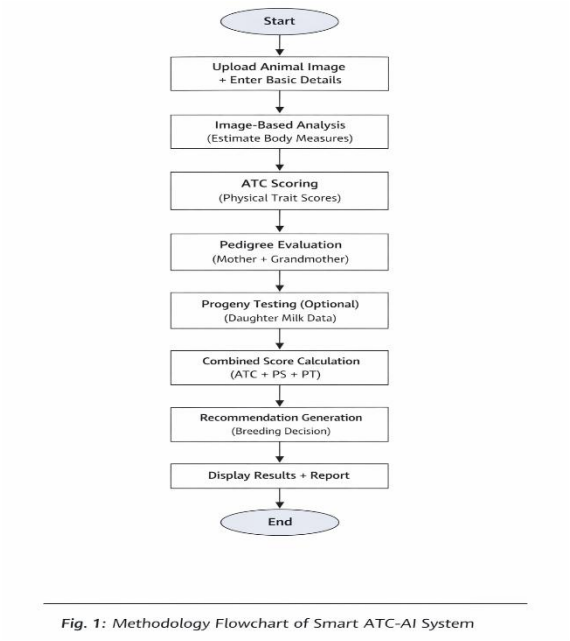

Fig. 1: Methodology Flowchart of Smart ATC-AI System

5.RESULTS AND DISCUSSION

A. System Performance

The system exhibits rapid processing times:
• ATC calculation: less than 500 milliseconds
• Other calculations: instantaneous

B. Precision and Reliability

The system yields accurate results in accordance with established protocols. Although not intended to replace professional assessment, it offers dependable recommendations.

C. Advantages to Users

• Less reliance on professionals
• Timesaving
• Effort-saving
• Improved decision-making
• Improved documentation

D. Restrictions

• Visual estimation is not entirely precise
• Online access required

4. FUTURE WORK

Future improvements may include:

- Integration of advanced AI models
- Expansion to more regional languages
- Offline functionality
- Integration with national livestock databases
- Mobile App Version

6. CONCLUSION

The Smart ATC-AI System offers an efficient solution to enhance dairy cattle evaluation through the incorporation of animal type classification (ATC), progeny testing (PT), and pedigree selection (PS) using an AI-driven web application. The application decreases the need for experts since farmers can easily upload images and data to receive accurate ratings and breeding advice. It helps in decision-making, improves record keeping, and ensures genetic enhancement of livestock, particularly dairy cows. While there may be some disadvantages like dependence on image analysis, internet connectivity is important, the application shows great potential in transforming livestock management and the sustainable development of the dairy industry.

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