# Autonomous mobile robot for disease detection and individual health monitoring of cattle in intensive dairy farms

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***Abstract***— *"Intensive farming methods" used in modern day dairy farms have resulted in a need for close monitoring of cattle health and early identification of diseases. The labour shortage faced by dairy industry, globally, has left farmers with no option but to go for automation. Current semi-automated systems used for cattle health monitoring, lack a non-invasive, real-time information system for individual health monitoring of cattle. As an attempt to address these issues, this research was done with the objective of finding out the suitability and feasibility of an "Autonomous Mobile Robot" to monitor cattle individually and update the stakeholders with real-time information. The design of the system involved a robot, programmed to navigate from one cow to another while cattle are being fed in "feeding stations". A visual-imaging camera and a thermographic camera were used as sensors to detect a set of physiological indicators corresponding to symptoms of popular cattle diseases. A "face recognition algorithm" was developed for cattle and images taken from both visual and thermographic cameras were processed to extract information about health condition of each cow. The information would then be communicated to the herdsmen via internet on a real-time, simplex communication system. Sensors used were capable of detecting two different physical parameters, namely, red color on facial area and body temperature of cattle. The algorithms were simulated using real-world imagery. Detection rates obtained through simulations proved the algorithms to be effective. Despite the high detection rates, some limitations which could hinder system performance such as poor barn conditions and inadequate system parameters were identified. However, as the barn conditions and design parameters could be modified and improved, the conclusion is that the mobile robot based system can fulfil the objectives of the research.*

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***Keywords***— *Intensive farming, Mobile robot, individual monitoring, Real-time communication*

## I. INTRODUCTION

Dairy industry has undergone revolutionary changes since the introduction of *intensive farming methods* in which the livestock is stocked at a high density inside barns, greatly replacing *free grazing models* that allow the animals to graze freely in open lands.

Cattle farms, traditionally were run by herdsmen who looked after a comparatively fewer number of cattle which allowed them to monitor each and every cattle individually. But with the embracement of intensive farming methods, compared to the number of herdsmen, the number of cattle accommodated in a barn has increased exponentially leaving the large herds to be looked after by a limited number of herdsmen.

Even though this growth in livestock has helped dairy farmers achieve *economies of scale*, it has exposed the farming operation to a number of risks and ethical implications. The risk of spread of diseases among cattle is extremely high in these barns as they are packed within a confined space and therefore early identification of diseases is of utmost importance. However, with the severe labour shortage faced by the dairy industry, globally [*2, 15*], close monitoring of cattle by herdsmen has become impractical.

With the development of sensor technology, researchers have been looking for ways to answer this issue with the detection of symptoms of diseases automatically by monitoring the physiological and behavioural indicators of cattle with sensors. Use of *Radio frequency identification (RFID)* tags on each cow has made it possible to track down each and every cow precisely. This has largely facilitated the use of sensor systems for monitoring cattle. The sensor systems currently used for this purpose can mainly be divided into two as *stationary* and *mobile* systems.

In stationary systems the sensors are placed at fixed locations in the barn. The rationale behind this is that the cattle in a barn have a repetitive daily routine and sensors can be fixed at locations where cows gather routinely (e.g.: Milking parlor, feeding station). Typical stationary sensors include surveillance cameras, temperature sensors, disposable taste sensors, thermographic cameras etc. Requirement of only a few number of sensors and the relatively simple technology behind it are the main benefits of this approach. However the limited individual attention given to each cow is the main drawback of it. Also the barn conditions (e.g.: poor lighting) often limit the amount of useful information that can be extracted from the monitoring process [*5*].

On the other hand mobile systems involve attaching the sensor to the cow's body or implanting the sensor inside the cow's body. Typical sensors include accelerometers, pedometers, GPS positioning sensors, pH sensors etc. This approach facilitates individual attention but mostly invasive in nature. The need for a large number of sensors, increases the initial capital investment. Also technologies like "GPS tracking" are more suitable for free-grazing models [*7, 9*].

Alongside with sensor technology, robotics technology has developed at a great pace over the last few decades. Areas such as industrial production processes, defense and military, entertainment, hospitality etc. have undergone amazing technological advances due to robots. Compared to these fields the dairy industry hasn't experienced much involvement of robots inside the barn [*11, 12*]. Researchers have developed *Auto-guided vehicles* to automate the processes such as milking and feeding of cattle, manure removal and barn cleaning etc. [*4*]. However there is plenty of potential for development of robotics technology in the area of disease identification and health monitoring of cattle in dairy farms.

Hence this paper is based on research work done to find out the feasibility and suitability of using an *autonomous mobile* robot for early detection of cattle diseases and developing a real-time information system to keep the herdsmen informed about the health condition of cattle.

## II. METHODOLOGY

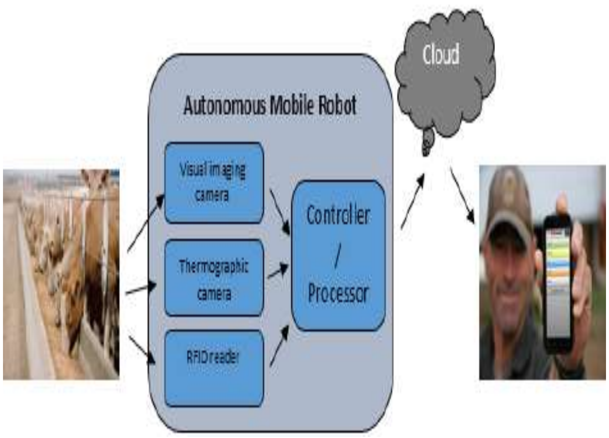


Figure 01: Information flow of the developed system

Development of the cattle health monitoring system can be divided into three main parts,

*a. Development of Autonomous Mobile Robot.*

The series of tasks expected to be performed by the *autonomous mobile robot* are getting near each and every cow in the herd, getting readings for a set of detectable physical parameters from each cow, processing data and communicating the information to stakeholders.

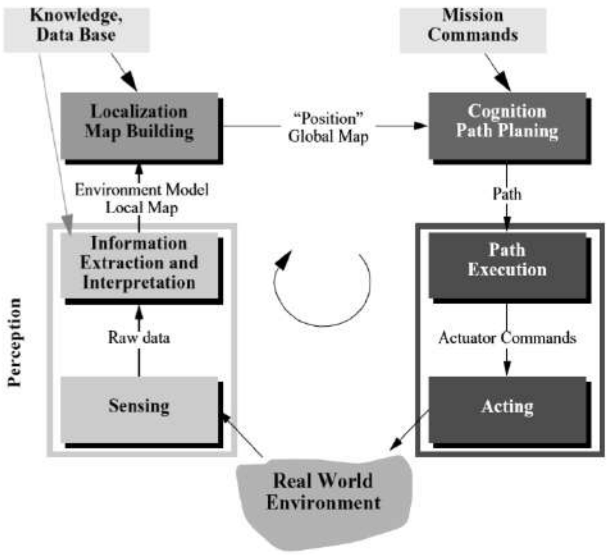


Figure 02: Reference control scheme for autonomous mobile robot [*14*]

The task of getting near each and every cow is simplified by the repetitive daily routine followed by cattle. "Feeding stations" are maintained inside barns to feed the livestock. These feeding stations are designed to prevent jostling or crowding. This provides an ideal opportunity for the mobile robot to get near cows without coming into direct contact with them. The robot can be programed to navigate from one cow to the next cow on its own and to avoid unexpected obstacles such as farming equipment standing in its way. Feeding intervals provide enough time for the batteries which power up the robot to be re-charged. The non-invasive methods used to monitor the cattle are believed not to cause any distress or discomfort to the animals.

The barn floor is often wet and slippery. And the feeding stations allow cattle to be monitored by the mobile robot with minimum changes to its orientation since the robot can navigate from one cow to the next with absolutely no change in its orientation unless it is disturbed by an obstacle.

Therefore a *Tracked-skid locomotion* mechanism is used by the autonomous mobile robot to move around as it provides larger traction and increases manoeuvrability in the loose terrain.

The robot is localized at the charging station where the batteries of the robot are charged prior to the cattle feeding session and is programmed to move to the first feeding slot at the beginning of the feeding period. The face of the cow is identified using an algorithm based on vibration. This is possible since the environment captured by the cameras is almost stationery except for the cattle being fed.

*b. Gathering data via sensors.*

Three types of sensors are attached to the end-effector, namely, visual imaging camera, thermographic camera and RFID reader. As the robot navigates in the feeding station the cows' face is detected by the visual imaging camera using a face detection algorithm.

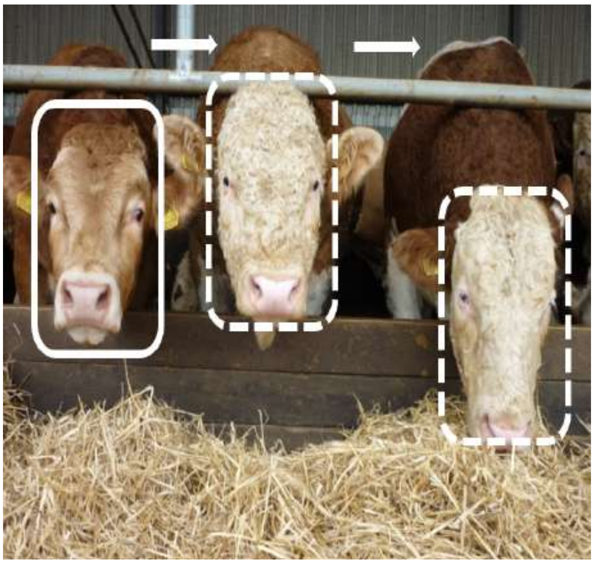

Figure 03: Detection and navigation sequence by the robot

Then the visual image of the face of each cow is sent to the processor to be processed to detect visual evidence for unusual blood patches or sore eyes. This is done using a technique known as *digital image thresholding*. The color image is converted to a binary image in search of red color.
Using the same technique on a thermal image of the cow taken by the thermographic camera can be used to detect high temperature of the whole body or individual body parts of the cow.
The RFID reader is used to identify each and every cow separately by transmitting a radio frequency signal to the RFID tag and receiving back the signal with information about cow's identity.

c. *Communicating data to the stakeholders*.
In order to realize the full use of the system, the information processed should immediately be communicated to the herdsmen. This is facilitated by wire-less communication between the robot and the herdsmen. A *Wi-Fi module* connected to the controller provides access to internet via Wi-Fi signals energized by a router in the barn.
In case a disease symptom is detected by the robot, the herdsmen will be immediately warned along with the information about potential diseases the detected cow may be suffering, via a *phone app* designed for this application.
The data gathered will also be stored using the *cloud technology* which is becoming increasingly popular in dairy industry with the new concept of *big data* [*8*] which facilitates the long term health monitoring of the herd.

## III. RESULTS AND DISCUSSION

The system developed was expected to detect two different parameters related to cattle health. They were,

- Red color on the visual image of the face.
- Body temperature beyond 39.5$^0$C.
  (Average body temperature of a healthy cow: 38.5$^0$C) [*1*]

These parameters correspond to symptoms of some of the most common cattle diseases in dairy industry such as "mastitis", "infectus rhinotracheitis" (red nose infection), "epistaxis" (bloody nose), "bovine bebesiosis" (tick fever) etc. [*3, 6, 13*].
Real-world images of 20 cows suffering from bloody nose, red nose infection and sore eyes and 20 images from healthy cows were simulated on software with a developed *digital image thresholding* program to find out the effectiveness of disease detection process. 15 of the diseased cows were correctly identified and 5 were overlooked due to inadequacy of red color in the image, poor contrast and poor brightness/ Lighting conditions (Detection rate: 75%). 18 of healthy cows were correctly identified and 2 were affected by noise (Detection rate: 90%).

Figure 04: Visual image and processed binary image

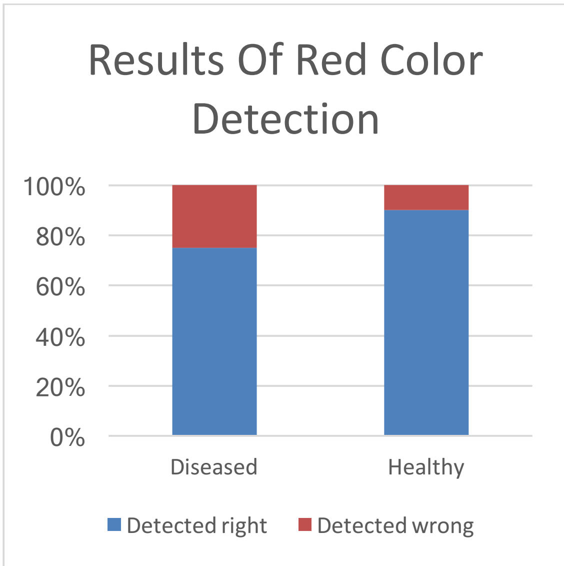


Figure 05: Results of red color detection

In this system the robot is programmed to get near cattle while they are being fed. Even though, this way, the chances of robot or cattle meeting with accidents by coming into contact with each other are minimized, monitoring cattle only in the feeding station, limits the amount of information gathered. For example, to detect the temperature of the cow's udder properly, a thermal image covering a significant part of the udder should be taken. But with the current model of taking readings at the feeding station, the angular range of coverage of each cow is limited since the feeding stations are designed with little gap between two adjacent cows. This problem can be solved to an extent by increasing the *degree of freedom* of the robot. However a better solution identified was to re-design the robot to take information during the *milking sessions*, which is expected to be done in future.

The details of the potential diseases (found by matching the diseases to the symptom/s detected) would be sent to the herdsmen along with the symptoms detected, detection time and the identity of the cow, as the main output of the system. This is expected to initiate prompt action by the herdsmen and give them a heads-up about the potential issue ahead of them (e.g.: what type of disease it could be and what kind of action needs to be taken based on their intuition). However the number of diseases which could be detected are limited by the number of symptoms that could be used on the robot. A bunch of more sensors would increase the scope of the robot as far as disease identification is concerned. However this will increase the time spent on each cow, which is around *1 minute* with the current system. Also the "processor speed" and "data communication speed" requirements will be major concerns.

During simulations of the initial design of the system developed, one major constrain identified was the limited space of the domain in which the mobile robot had to work. This was due to the limited range of the Wi-Fi router. This made the system ineffective to be used in large intensive farms with many thousands of cattle. However using "Wi-Fi boosters and extenders" the range could be increased significantly.

Since the robot uses a visual camera for its monitoring, the lighting conditions of images taken in the barn were proven to have a significant impact on the final outcome, during simulations. Attaching a flash-light along with the lighting conditions cannot be accepted since it could cause distress or discomfort to the cattle that can affect its routine activities.

The time taken by the robot to monitor one cow is around 1 minute. This can be a limitation when it comes to large herds. The state-of-art navigation system, which is known as "vertical take-off and landing drones" could be used to perform many of the tasks performed by this system within a very shorter period of time. However the biggest challenge in doing so is the limited range of RFID sensors. It is expected to overcome this issue as an extension to this research.

## IV. CONCLUSION

Since *intensive dairy farming* methods are highly prone to quick spread of diseases among the herd, regular close monitoring of each cattle is of utmost importance. However with the labor shortage faced by the dairy industry all over the globe, automation of processes can be considered the best alternative. The *Autonomous Mobile Robot* based system for health monitoring and disease identification of cattle, not only allows the process of monitoring cattle to be automated but also builds a platform for the herdsmen to react immediately and to maintain long term records about the health conditions of the herd which facilitates effective health monitoring of the cattle in intensive dairy farms.

On the other hand, the robotics and communication technologies used in this research are less sophisticated. Most of the technologies used have already proven to work with similar applications in different fields. Therefore based on this research it can be stated that an *autonomous mobile robot* is suitable and feasible to be used for early detection of cattle diseases and development of a real-time information system to keep the farm managers informed about the health condition of cattle in an intensive dairy farm.

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