

MUZZLE BIOMETRICS AND ARTIFICIAL INTELLIGENCE FOR SMARTER CATTLE IDENTIFICATION

Tanya Chaudhary¹ and Suryansh Singh²

¹Research associate, Dr. D. P. Rastogi Central Research Institute of Homeopathy,

²Consultant, Bureau of Indian Standards

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Abstract

Reliable identification of individual animals is the backbone of effective livestock management, supporting everything from health records and breeding programmes to disease surveillance and traceability. While conventional methods such as ear tags, branding and RFID have been widely used, they are not without limitations. Muzzle biometrics, which relies on the unique pattern of grooves and ridges on the bovine muzzle, offers a simple, non-invasive and permanent alternative. This article explores the evolution of muzzle-based identification, from traditional printometry to modern artificial intelligence (AI)-driven image recognition. It also highlights the growing role of computer vision and machine learning in developing accurate, automated identification systems and discusses their potential applications in precision livestock farming, insurance, ownership verification and disease control. Although further field validation is needed, AI-enabled muzzle recognition represents a promising step towards smarter, welfare-friendly and more reliable livestock identification in the digital era.

Introduction

Accurate identification is the foundation of organised livestock production. Every meaningful farm record—birth date, pedigree, vaccination, disease history, milk yield, breeding status, ownership and insurance—must ultimately be linked to the correct animal. When identification fails, even well-maintained records lose much of their value. For decades, livestock owners have depended on ear tags, tattoos, branding and, more recently, radio-frequency identification devices. Although these methods remain valuable, each has limitations. Ear tags may be lost, damaged, exchanged or deliberately removed. Tattoos are often difficult to read and require close restraint. Branding raises animal-welfare concerns, while electronic devices involve additional equipment, expenditure and, in some cases, risks of breakage, migration or tampering.

These shortcomings have stimulated interest in biometric identification—recognising an animal through a naturally occurring anatomical characteristic rather than

an externally attached label. Among the available biological identifiers, the muzzle pattern of cattle and buffaloes offers a particularly promising combination of uniqueness, accessibility and non-invasive image acquisition.

A bovine fingerprint

The hairless, moist surface surrounding the nostrils of cattle is known as the *planum nasolabiale*. Its surface is not smooth. It contains a complex arrangement of elevations, depressions, grooves and island-like structures that collectively form the animal's muzzle dermatoglyph. The term *dermatoglyphics* originates from the Greek words *derma*, meaning skin, and *glyph*, meaning carving. In cattle, the concept is comparable to the use of fingerprints in humans. Although two muzzles may appear similar during casual observation, closer examination reveals differences in the number, shape, direction, branching and distribution of their surface features. The

principal structures commonly described in a muzzle print include:

- **Beads:** rounded, oval or irregular island-like elevations;
- **Ridges:** elongated, straight or curved structures, which may be single or branched;
- **Clustered beads:** groups of closely arranged beads;
- **Valleys:** relatively clear spaces separating adjoining structures; and
- **Grooves:** prominent channels that may vary in location, length, completeness and shape.

Researchers have divided muzzle prints into basal, middle and upper sectors on the left and right sides so that their characteristics can be systematically recorded. Prints have also been classified as grooved, non-grooved or special patterns and, according to the arrangement of ridges, as branched, parallel or granular. Early investigations involving large numbers of animals suggested that two individuals do not possess exactly identical muzzle patterns. The pattern is also considered sufficiently stable during the animal's life to serve as a permanent biological identifier. This combination of distinctiveness and persistence is precisely what is required from a useful biometric trait. Differences in muzzle dermatoglyphics have additionally been reported among cattle types and breeds. The distribution of beads, ridges, hair pits and grooves may therefore contribute not only to individual recognition but also, when interpreted carefully, to breed characterisation.

From ink and paper to digital cameras

The earliest muzzle-recording procedures resembled fingerprint collection. The muzzle was restrained, cleaned and dried before applying stamp-pad ink or cyclostyle ink. A sheet of white paper was then pressed evenly against the muzzle to obtain an impression. Several refinements were introduced to improve print quality. Metal pads, rollers, sweat-absorbing pads, thick

paper and antiperspirant preparations were used to reduce smudging and prevent moisture from merging the finer structures. Stamp-pad ink was often preferred because it dried quickly and was less irritating than certain printing inks. These techniques made systematic muzzle printometry possible, but they were not always convenient under field conditions. Obtaining a complete impression required suitable restraint, careful pressure and control of moisture. Excessive ink produced blurred prints, whereas insufficient ink failed to capture fine details. Paper prints also had to be labelled, stored and manually compared.

Digital photography transformed the process. Instead of transferring the pattern onto paper, the muzzle could be photographed directly. Digital acquisition was faster, cleaner and better suited to computer-assisted comparison. It also eliminated much of the variation caused by uneven pressure during conventional printing. However, digital imaging introduced another set of challenges. The appearance of a muzzle can change with camera angle, distance, illumination, moisture, dirt, movement and partial obstruction. The nostrils may also deform slightly as the animal breathes or moves its lips. Consequently, a successful digital system must recognise the underlying pattern despite these variations. A standard image-acquisition protocol is therefore essential. The muzzle should ideally be clean, evenly illuminated and photographed from the front at a consistent distance. Both nostrils and the central muzzle region must remain visible, and images that are blurred, severely tilted or overexposed should be rejected before registration.

Why existing identification systems still need support?

Mechanical and electronic identification methods should not be dismissed; rather, their limitations demonstrate why a complementary biometric system is valuable. Plastic ear tags are inexpensive, visible and easy to use, but they

may tear through the ear, become illegible or be removed. Tattooing provides a more permanent mark but requires close handling and may be difficult to read in darkly pigmented ears. Freeze branding can be observed from a distance, yet it is mainly effective in dark-coated animals and permanently alters their appearance. Electronic identification improves the speed of data recording. RFID ear tags, injectable transponders and ruminal boluses can store or communicate an individual code. Nevertheless, they remain physical devices. Ear tags can be lost; injectable transponders may migrate or fail; ruminal boluses require specialised readers and may be relatively expensive.

DNA profiling offers extremely high accuracy and is especially valuable for parentage verification, forensic investigation and meat traceability. However, sample collection, laboratory processing and analysis make it unsuitable as the sole method for rapid everyday recognition of animals at a farm gate or milking parlour. Iris and retinal patterns are also distinctive, but their capture generally requires controlled positioning and specialised optical equipment. Muzzle recognition occupies a useful middle ground. The trait is naturally present, externally visible and can be captured without piercing, branding or implanting a device. A farmer or field worker could potentially photograph an animal using a mobile phone and compare it with an authorised database.

Teaching a computer to recognise cattle

Digital muzzle identification depends on converting a photograph into a numerical representation that can be compared with stored images. Early computer-vision systems relied on manually designed image descriptors. Techniques such as principal component analysis, scale-invariant feature transform and speeded-up robust features were used to identify informative points, edges and textures within muzzle images. A matching algorithm compared these features

with those recorded in a database and produced a similarity score.

These approaches demonstrated that automated muzzle recognition was feasible. They could, however, be affected by image rotation, noise, changes in illumination and variation in muzzle positioning. Image preprocessing—including cropping, contrast enhancement, noise removal and geometric correction—was often necessary before feature extraction. Machine learning has substantially expanded these possibilities. In supervised learning, the computer is supplied with muzzle images whose animal identities are already known. During training, the model learns which combinations of visual features consistently distinguish one animal from another. It can then predict the identity of a muzzle image that it has not previously encountered.

Artificial neural networks process information through connected layers of computational units. Convolutional neural networks are especially suited to images because they learn spatial features progressively. Initial layers may detect edges and local texture; deeper layers combine them into more complex patterns; and the final layers associate those patterns with an individual identity. Deep-learning systems can reduce dependence on manually selected features. Architectures such as convolutional networks and compact models designed for mobile devices have already been explored for recognising cattle, goats, dogs and other species from facial, coat or nose patterns. Recent livestock identification research increasingly combines computer vision, deep learning and cloud- or mobile-based data management.

Beyond identity: traceability and smart farming

A reliable muzzle-recognition system could strengthen livestock management at several levels such as :-

Farm records and precision management

Once an animal is recognised, its digital profile could immediately display

vaccination status, breeding history, lactation stage, treatment records and production data. This would reduce transcription errors and help ensure that medication, feeding or reproductive interventions are directed to the intended animal.

Livestock insurance

Animal substitution is a persistent concern in livestock insurance. An ear tag can be shifted from one animal to another, whereas a biometric pattern is part of the animal itself. Registering muzzle images at the time of insurance and comparing them during claim verification could provide an additional safeguard against duplicate or fraudulent claims.

Ownership and transactions

Muzzle biometrics may assist in confirming ownership during sale, purchase, transport and dispute resolution. A securely time-stamped record could link the animal to its farm, owner and transaction history without permanently disfiguring it.

Disease control and food-chain traceability

Rapid identification is critical during outbreaks. Linking biometric identity with movement, vaccination and health records could improve tracing of contact animals and reduce errors caused by missing or unreadable tags. At a broader level, such systems could support transparent movement from farm to market and enhance consumer confidence.

Selection and automated monitoring

When muzzle identity is connected to cameras in a milking parlour, feeding station or weighing area, production and behavioural observations may be assigned automatically to the correct animal. Individual recognition is thus not merely an end point; it is the gateway through which automated livestock-monitoring data become biologically meaningful.

Can the muzzle predict age, weight or production?

Muzzle research has not been restricted to identification. Several investigators have examined whether muzzle dimensions or dermatoglyphic characteristics

are associated with age, body weight, milk yield and milk composition. As an animal grows, measurements such as muzzle width, basal length, central length, muzzle span, muzzle length and total muzzle area may increase. Regression models developed in cattle and buffaloes have therefore shown potential for estimating body weight, particularly when several muzzle measurements are considered together.

Some studies have also reported associations between muzzle dimensions and lactation traits. Muzzle width, basal length, distance between nostrils and muzzle area have, in particular datasets, shown positive relationships with milk yield or body weight. Certain dermatoglyphic features have also been evaluated in relation to milk constituents and age at first calving. These findings are scientifically interesting, but they require cautious interpretation. Relationships have not been uniform across breeds, age groups or studies. Correlations between bead or ridge counts and milk production have sometimes been weak, negative or statistically non-significant. An association observed in one herd cannot automatically be treated as a universal biological rule.

Muzzle dimensions may partly reflect overall skeletal growth, breed, sex and age, which could explain their relationship with body weight. Milk production, by contrast, is influenced by genetics, parity, nutrition, health, environment, stage of lactation and management. It would therefore be premature to select replacement animals solely from their muzzle structure. At present, individual identification is the strongest and most defensible application of muzzle biometrics. Prediction of age, weight or production should be regarded as an emerging research area requiring larger, breed-specific and independently validated datasets.

The road from laboratory to livestock farm

Despite its potential, muzzle recognition must overcome several practical barriers before widespread adoption. First, databases must include large numbers of

animals photographed repeatedly under realistic field conditions. A model trained only on clear laboratory images may perform poorly when faced with mud, saliva, shadows, sunlight, movement or low-cost mobile cameras.

Second, algorithms should be evaluated not merely by overall accuracy but also by false acceptance and false rejection rates. A system that incorrectly assigns one animal's identity to another could have serious consequences for insurance, disease certification or ownership. Third, the system must accommodate changes associated with growth, minor injury, pigmentation, moisture and image quality. Longitudinal studies are needed to establish how reliably a calf registered early in life can be recognised as an adult. Fourth, data governance deserves as much attention as algorithm development. Biometric images, ownership information and movement records must be stored securely. Registration procedures should prevent duplicate enrolment, and authorised corrections should leave a transparent audit trail.

Finally, technology must remain affordable and simple. A solution requiring expensive cameras, constant high-speed internet and complex animal restraint will have limited value for smallholder farmers. The most useful platform may be a lightweight smartphone application capable of checking image quality, capturing the muzzle, generating a biometric template and synchronising with a secure database when connectivity becomes available.

A natural identity for the digital livestock era

The cattle muzzle represents an elegant convergence of anatomy, veterinary management and artificial intelligence. What began as an ink impression on paper can now be transformed into a searchable digital identity. Muzzle biometrics will not necessarily replace every ear tag, RFID device or DNA test. Its immediate value lies in strengthening them. A visible tag can provide

rapid field recognition, RFID can support automatic data transfer, and DNA can resolve high-stakes forensic questions and the muzzle can verify that all these records truly belong to the animal standing in front of the observer.

For countries with large and diverse livestock populations, including India, such multi-layered identification could improve breeding records, insurance verification, disease surveillance, welfare monitoring and traceability. The technology is especially attractive because the identifier is already present on every animal and can be recorded without pain. The future challenge is no longer to prove that cattle muzzles are different. It is to build sufficiently inclusive and field-ready systems that can recognise those differences reliably. With sound veterinary validation, standardised image collection and responsible deployment, the bovine nose may become a powerful passport for livestock in the age of precision farming.

Conclusion

The unique dermatoglyphic pattern of the bovine muzzle has emerged as a promising biometric tool for accurate and non-invasive animal identification. Unlike conventional methods, such as ear tags and branding, muzzle biometrics provides a permanent biological identity that cannot be easily lost, altered or duplicated. Recent advances in digital imaging, computer vision and artificial intelligence have further enhanced the feasibility of automated muzzle recognition, making it a practical option for modern livestock management. Beyond individual animal identification, AI-enabled muzzle recognition has the potential to strengthen traceability, improve disease surveillance, support livestock insurance, simplify ownership verification and facilitate precision livestock farming.

Although further research is needed to develop standardised image acquisition protocols, large-scale databases and robust field validation across different breeds and production systems, the technology shows immense promise. As livestock farming

becomes increasingly digital, integrating existing identification methods, muzzle muzzle biometrics with AI and smart farm recognition is likely to complement them, management systems could provide a reliable, paving the way for more secure, efficient and welfare-friendly and cost-effective sustainable livestock management in the identification solution. Rather than replacing future.

References

- Ahmed, S., Gaber, T., Tharwat, A., Hassanien, A.E. and Snáel, V. (2015). Muzzle-based cattle identification using speeded-up robust feature approach. *Proceedings of the International Conference on Intelligent Networking and Collaborative Systems*, 99–104.
- Al-Anbari, N.N. and Al-Samarai, F.R. (2009). Muzzle dermatoglyphics of Holstein cattle and its applicability in predicting major milk constituents. *Life Science International Journal*, **3**(2), 1126–1129.
- Awad, A.I., Zawbaa, H.M., Mahmoud, H.A., Nabi, E.H.H.A., Fayed, R.H. and Hassanien, A.E. (2013). A robust cattle identification scheme using muzzle print images. *Proceedings of the Federated Conference on Computer Science and Information Systems*, 529–534.
- Bello, R.W., Talib, A.Z.H. and Mohamed, A.S.A.B. (2020). Deep-learning-based architectures for recognition of cows using nose-image patterns. *Gazi University Journal of Science*, **33**(3), 831–844.
- Chopade, S.S. and Khire, D.W. (2009). Studies on the growth pattern of the muzzle of various cattle breeds. *Indian Journal of Field Veterinarians*, **4**, 23–26.
- Chopade, S.S. and Khire, D.W. (2016). Use of muzzle printometry in identification, age prediction and production performance of Surti buffaloes. *Imperial Journal of Interdisciplinary Research*, **2**(9), 745–748.
- Dac, H.H., Gonzalez Viejo, C., Lipovetzky, N., Tongson, E., Dunshea, F.R. and Fuentes, S. (2022). Livestock identification using deep learning for traceability. *Sensors*, **22**(21), 8256.
- Gaber, T., Tharwat, A., Hassanien, A.E. and Snasel, V. (2016). Biometric cattle identification based on Weber's local descriptor and an AdaBoost classifier. *Computers and Electronics in Agriculture*, **122**, 55–66.
- Hossain, M.E., Kabir, M.A., Zheng, L., Swain, D.L., McGrath, S. and Medway, J. (2022). A systematic review of machine-learning techniques for cattle identification: datasets, methods and future directions. *Artificial Intelligence in Agriculture*, **6**, 138–155.
- Indrabayu, I.N., Intan, S.A. and Bugiwati, S.R.A. (2020). Portable cattle tagging based on muzzle patterns. *International Journal of Interactive Mobile Technologies*, **14**(13), 134.
- Noviyanto, A. and Arymurthy, A.M. (2013). Beef cattle identification based on muzzle patterns using a matching-refinement technique in the SIFT method. *Computers and Electronics in Agriculture*, **99**, 77–84.

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