ANIMAL FACE RECOGNITION: A SYSTEMATIC LITERATURE MAPPING

Kaio Felipe Barbosa Garcia
Universidade Estadual do Norte do Paraná
Bandeirantes-Paraná
http://lattes.cnpq.br/9138353086453679

José Reinaldo Merlin
Universidade Estadual do Norte do Paraná
Bandeirantes-Paraná
http://lattes.cnpq.br/0840048221330827

ABSTRACT: Systematic Literature Mapping is a scientific study that gathers relevant works to answer the questions formulated by the author. In this article, the results of a Systematic Literature Mapping on the use of facial recognition in animals in various contexts (Farm, Nature, Animal Protection, etc...) are presented. The search was conducted through Google Academic and publications from the last twenty years (2012-2022) were selected and analyzed. From these literatures the research motivations, technologies used, methodology, recognition strategies, advantages of use, difficulties of application, and which animals are the focus of the literature were extracted. The benefits of using this technology are clear, a way to identify animals and collect important data about them in a non-invasive way for the animal. Therefore, the area of animal recognition is subject to a great advance and from the mapping results it was possible to notice a potential for practical application of this technology, its use both on farms for data collection and even its ability to identify individuals of endangered species.
KEYWORDS: Face Recognition; Animals; Systematic Literature Mapping.

RECONHECIMENTO FACIAL DE ANIMAIS: MAPEAMENTO SISTEMÁTICO DA LITERATURA

RESUMO: Mapeamento Sistemático de Literatura consiste em um estudo científico que reúne trabalhos relevantes para responder às questões formuladas pelo autor. Neste artigo são apresentados os resultados de um Mapeamento Sistemático da Literatura sobre o uso de reconhecimento facial em animais em vários contextos (Fazenda, Natureza, Proteção Animal, etc…). A pesquisa foi realizada por meio do Google Acadêmico e foram selecionadas e analisadas publicações dos últimos vinte anos (2012-2022). Destas literaturas foram extraídas as motivações da pesquisa, tecnologias utilizadas, metodologia, estratégias de reconhecimento, vantagens

da utilização, dificuldades de aplicação e quais animais são o foco da literatura. Os benefícios do uso dessa tecnologia são claros, um jeito de identificar animais e coletar dados importantes sobre eles de uma maneira não invasiva ao animal. Por isso, a área do reconhecimento de animais está sujeita a um grande avanço e pelos resultados do mapeamento foi possível notar um potencial de aplicação prática dessa tecnologia, seu uso tanto em fazendas para a coleta de dados e até mesmo sua capacidade de identificar indivíduos de espécies ameaçadas.

PALAVRAS-CHAVE: Reconhecimento Facial; Animais; Revisão Sistemática da Literatura.

1 | INTRODUCTION

Face recognition is the technique where it is possible to recognize characteristic patterns of humans and animals faces. When applied in the area of animal husbandry farms can be used to identify, monitor, and to obtain individual data and thus assist in their care.

Among the methods of identification and recognition in use, facial recognition is the unique non-invasive to animals, i.e., it is a technique which doesn't cause any physical harm to individuals, different from other techniques frequently used. The identifying earrings and RFID tags are examples of methods which cause pain in the application because they need to be attached to the animal and can cause infections at the area over time.

The technology has the potential to assist in research involving wild and endangered animals, performing tasks such as monitoring, identifying, and cataloging the individuals of various species, for example.

2 | METHODOLOGY

The following steps were followed to produce this work: Planning, Conducting, and Presenting the Results. The methodology used in this work was based on the one proposed by Barbara Kitchenham in the 2004 article "Procedures for performing systematic reviews", but some changes and modernizations were made throughout the work, because it is a study of a very current technological area.

The first step was to select several articles that contained the theme in their titles. These articles are presented in Section 4.1.

3 | RESEARCH QUESTIONS

Some questions were elaborated in order to be able to present relevant information about the topic (Animal Face Recognition).

- **RQ1:** What is the application area of the algorithms?

- **RQ2:** What is the motivation for using facial recognition?

- **RQ3:** Which animals are identified by the algorithms?

- **RQ4:** What is the strategy to do the recognition?

- **RQ5:** What are the challenges of applying this method?
- **RQ6:** Which technologies were used in the development?
- **RQ7:** What methodology was applied?

4 | SEARCH PROCESS

The literature search was done using Google Academics, giving priority to papers written in English. Some of these articles were available in full and others were accessed via the university access. The sources where the articles are published and their acronyms used for identification throughout the paper are presented in Table 1.

ID	Sources
CEA	Computers and Eletronics in Agricuture
ACM	Association for Computing Machinery
AIICAAS	Agricultural Information Institute od CAAS
GUJS	Gazi University Journal of Science
IJACSA	International Journal of Advanceed Computer Science and Applications
ICIIP	2015 Third International Conference on Image Information Processing
IEEE	Institute of Electrical and Electronics Engineers
ARSCB	Annals of the Romanian Society for Cell Biology
PNAS	Proceedings of the National Academy of Sciences
IOPCS	IOP Conference Series: Earth and Environmental Science
ASABE	American Society of Agricultural and Biological Engineers
ITETMTA	ITE Transactions on Media Technology and Applications
MPE	Mathematical Problems in Engineering
EE	Ecology and Evolution
UCS	Universidade de Caxias do Sul - Área do Conhecimento de Ciências Exatas e Engenharias
BMCZ	BMC Zoology
JPCS	Journal of Physics: Conference Series
CI	Computers in Industry
SA	Science Advances
CCBR	Chinese Conference on Biometric Recognition
PO	Plos One
BBR	Behavioural Brain Research

Table 1: Sources of Research

4.1 Found Articles

Twenty-five articles were found on the subject, and these are shown in Table 2, along

with the name of the journal in which they were published.

1:	"An adaptive pig face recognition approach using Convolutional Neural Networks"
2:	"Cow Face Detection and Recognition Based on Automatic Feature Extraction Algorithm"
3:	"Deep Cross-Species Feature Learning for Animal Face Recognition via Residual Interspecies Equivariant Network"
4:	"Deep Learning-Based Architectures for Recognition of Cow Using Cow Nose Image Pattern"
5:	"Image-based Individual Cow Recognition using Body Patterns"
6:	"Face Recognition of Cattle"
7:	"Giant Panda Face Recognition Using Small Datase"
8:	"Creature Face Recognition Using Neural Networks"
9:	"Face Recognition of Cattle: Can it be Done?"
10:	"Research on pig face recognition model based on keras convolutional neural network"
11:	"Pig Face Recognition Model Based on a Cascaded Network"
12:	"Pig Face Recognition Using Eigenspace Method"
13:	"Open Set Sheep Face Recognition Based on Euclidean Space Metric"
14:	"Automated facial recognition for wildlife that lack unique markings: A deep learning approach for brown bears"
15:	"Reconhecimento facial bovino: uma alternativa aos métodos tradicionais de rastreio"
16:	"LemurFaceID: a face recognition system to facilitate individual identification of lemurs"
17:	"A pig face recognition method for distinguishing features"
18:	"Dairy Cow Tiny Face Recognition Based on Convolutional Neural Networks"
19:	"Fast Recognition of Pig Faces Based on Improved Yolov3"
20:	"Two-stage method based on triplet margin loss for pig face recognition"
21:	"Individual Recognition in Domestic Cattle (Bos taurus): Evidence from 2D-Images of Heads from Different Breeds"
22:	"Picture recognition in animals and humans"
23:	"Face recognition in primates: a cross-species study"
24:	"Towards on-farm pig face recognition using convolutional neural networks"
25:	"Chimpanzee face recognition from videos in the wild using deep learning"

Table 1: Articles found in google academics Search

4.2 Inclusion and exclusion criteria

The search process was divided into two parts. First, the titles and abstracts were read and analyzed to select those that fit the theme, and about thirty were chosen. Then the selected articles were read and the inclusion and exclusion criteria, presented in Table 3, were applied, resulting in twenty selected articles.

Inclusion Criteria	
IC1:	Publications between 2012 and 2022.
IC2:	Written in English (exception made for T15).
IC3:	Papers that make use of Facial Recognition in Animals.
IC4:	Preference for free papers, or possible to access with the university.
Exclusion Criteria	
EC1:	Publications prior to 2012.
EC2:	Duplicate papers or old versions.
EC3:	Papers that are not consistent with the topic.
EC4:	Languages other than English or Portuguese.

Table 3: Inclusion and Exclusion Criteria

4.3 Data extraction

Next we have the information relevant to the mapping that was extracted from the selected literature:

Papers Information:

- Reference, event, or place of publication.

- Objectives of the work.

- Content covered.

- Technologies used.

- Results.

The data collected was stored in spreadsheets and in notes for use in the next stages of the mapping.

4.4 Quality Evaluation

According to author Barbara Kitchenham, the application of Quality Assessment (QA) is a complementary way of evaluating and ensuring the quality of primary studies, in addition to the inclusion and exclusion criteria. It is intended to be used as a way of weighing the importance of individual studies and ensuring that they have relevance to the developed mapping.

- **QA1:** Do the studies clearly present their objectives?

- **QA2:** Do the studies present the technologies and tools used?

- **QA3:** Do the studies present the tests or practical application of the algorithms developed?

- **QA4:** Do the studies clearly expose the results obtained?

These were the QA criteria used to evaluate the relevance of the papers, superficially

but sufficiently to eliminate studies that were not relevant to the mapping. The scores for each criterion were: 0 - does not present / 0.25 - presents briefly / 0.5 - presents with lack of detail / 0.75 - presents completely / 1 - presents perfectly; papers that presented a final score below 2 would be discarded for not being adequate. All twenty papers were successful in these categories as shown in Table 4, which shows that their data are well presented and relevant to the present mapping.

Article	QA1	QA2	QA3	QA4	TOTAL
T1	1	1	1	1	4
T2	1	1	0.75	1	3.75
T3	1	1	0.5	1	3.5
T4	1	1	1	1	4
T5	1	1	1	1	5
T6	1	0.75	1	1	3.75
T7	1	1	1	1	4
T8	1	1	1	0.75	3.75
T9	0.75	0.75	0.5	1	3
T10	1	1	1	1	4
T11	1	0.75	1	1	3.75
T12	0.75	0.75	0.75	1	3.75
T13	1	1	1	1	4
T14	1	1	1	1	4
T15	1	1	0.75	1	3.75
T16	1	0.75	1	1	3.75
T17	1	0.75	0.5	1	3.25
T18	1	1	0.75	1	3.75
T19	1	1	1	1	4
T20	1	0.5	0.75	1	3.25

Table 4: Quality Evaluation

5 | RQ RESULTS

The results obtained through an analysis on the answers of the proposed RQs are presented below, the identifiers of the papers follow Table 5.

ID	Title	Reference	Source	Year
T1	"An adaptive pig face recognition approach using Convolutional NeuralNetworks"	Marsot et al. (2020)	CEA	2020
T2	"Cow Face Detection and Recognition Based on Automatic Feature Extraction Algorithm"	Yao et al. (2019)	ACM	2019
T3	"Deep Cross-Species Feature Learning for Animal Face Recognition via Residual Interspecies Equivariant Network"	Shi et al. (2020)	AIICAAs	2020
T4	"Deep Learning-Based Architectures for Recognition of Cow Using Cow Nose Image Pattern"	Bello, Talib and Mohamed (2020)	GUJS	2020
T5	"Image-based Individual Cow Recognition using Body Patterns"	Bello et al. (2020)	IJACSA	2020
T6	"Face Recognition of Cattle"	Kumar et al. (2015)	ICIIP	2015
T7	"Giant Panda Face Recognition Using Small Dataset"	Matkowski et al. (2019)	IEEE	2019
T8	"Creature Face Recognition Using Neural Networks"	Mathur et al. (2021)	ARSCB	2021
T9	"Face Recognition of Cattle: Can it be Done?"	Kumar et al. (2016)	PNAS	2016
T10	"Research on pig face recognition model based on keras convolutional neural network"	Wang et al. (2020)	IOPCS	2020
T11	"Pig Face Recognition Model Based on a Cascaded Network"	Wang et al. (2021)	ASABE	2021
T12	"Pig Face Recognition Using Eigenspace Method"	Wada et al. (2013)	ITETMTA	2013
T13	"Open Set Sheep Face Recognition Based on Euclidean Space Metric"	Xue et al. (2021)	MPE	2021
T14	"Automated facial recognition for wildlife that lack unique markings: A deep learning approach for brown bears"	Clapham et al. (2020)	EE	2020
T15	"Reconhecimento facial bovino: uma alternativa aos métodos tradicionais de rastreio"	Brito (2021)	UCS	2021
T16	"LemurFaceID: a face recognition system to facilitate individual identification of lemurs"	Crouse et al. (2017)	BMCZ	2017
T17	"A pig face recognition method for distinguishing features"	Shigang et al. (2021)	IEEE	2021
T18	"Fast Recognition of Pig Faces Based on Improved Yolov3"	Li et al. (2022)	JPCS	2022
T19	"Towards on-farm pig face recognition using convolutional neural networks"	Hansen et al. (2018)	CI	2018
T20	"Chimpanzee face recognition from videos in the wild using deep learning"	Schofield et al. (2019)	SA	2019

Table 5: Primary studies selected

RQ1 - What is the application area of the algorithms?

Seventy percent (70%) (14) of the mapped papers [T1, T2, T4, T6, T9, T10, T11, T12, T13, T15, T17, T18, and T19] contain algorithms that have been or will be applied on livestock farms with a focus on improving animal control, welfare and health.

In addition to farms, thirty percent (30%) (6) [T3, T7, T8, T14, T16, and T20] were made to assist in the surveillance and/or protection of rare animals, also acting in studies involving wild species such as lemurs or pandas, animals studied among the literatures.

RQ2 - What is the motivation for using facial recognition?

The algorithms proposed in eighty percent (80%) (16) of the papers [T1, T2, T4, T5, T6, T7, T8, T9, T10, T11, T12, T13, T15, T17, T18, and T19] were created to replace outdated methods of tracking and identifying animals, both on farms and wild animals under observation. RFID tags were cited in six papers as the most used method, but they have their disadvantages, such as pain in application, chance of infection, and the fact cited in the paper "Towards on-farm pig face recognition using convolutional neural networks", that says the tag has a maximum reading distance (120cm).

In these sixteen papers, which represent the eighty percent cited above, the improvements that the use of the proposed algorithms would bring are discussed, such as the advancement in animal welfare control (health, food safety, etc.), the increase in production (in the case of dairy cows), crime prevention, among other improvements.

In addition to the focus on farm animals, this technology was also featured in twenty percent (20%) (4) of the papers [T3, T14, T16, and T20] being used to monitor wild animals entering urban areas, in short or long term conservation and investigation of animals in their habitats, collecting data such as the presence, abundance, distribution, and behavior of wild species.

RQ3: Which animals are identified by the algorithms?

Among all the articles found, some kind of animal was the "focus" of the research and development of recognition, some as mentioned in the previous QR, from these animals, pigs were the most highlighted animals, being the focus of recognition in thirty-five percent (35%) (7) of the works [T1, T10, T11, T12, T17, T18, and T19], while cattle were in thirty percent (30%) (6) [T2, T4, T5, T6, T9, and T15].

Sheep and other more exotic species such as brown bears [T14], pandas [T7], lemurs [T16], and chimpanzees [T20], appeared in only one of the literatures and each one has five percent (5%) of presence in the total works and finally two publications [T3 and T8] left open which animal would be recognized, ten percent (10%).

RQ4: What is the strategy to do the recognition?

Among the strategies found, almost all the works (90%) [T1, T2, T3, T6, T7, T8, T9, T10, T11, T12, T13, T14, T15, T16, T17, T18, T19, T20] chose to follow the pattern and search for features on the animals' faces and analyze them to obtain the results. But T4 and T5 followed two different strategies, where T4 performed the recognition based on "fingerprints" found on the bovine's snouts, analyzing the patterns in their relief, their depressions and elevations. Finally, T5 brought an analysis on the patterns of spots found on the cattle's hides, thus analyzing them to obtain a pattern and provide a result.

RQ5: What are the challenges of applying this method?

As with every creation process the authors of the papers experienced challenges and difficulties when developing the algorithms, the main and most encountered was during the initial acquisition phase, where seventy-five percent (75%) (15) of the papers [T1, T2, T3, T4, T5, T6, T7, T9, T10, T12, T13, T14, T15, T19, and T20] encountered obstacles in this phase which is of paramount importance for recognition.

In the acquisition phase of the data that will be analyzed, some difficulties were encountered in dealing with variables that may appear during the acquisition of data for training and testing, among these variables we can highlight some such as lighting and image background, position of the animal, dirt and other things that can obstruct the animal's face. The low quality and quantity of data to perform training was a frequent problem in works that focused on monitoring wild animals, pandas for example [T7], which lack of datasets because it is a rare species.

Moving on to the next phases we have some difficulties such as classification of very similar animals [T11], extracting few features from faces [T17], difficulties with monitoring [T16] and low recognition accuracy [T18], each of these problems were found in one (5% each) of the papers. Finally, one paper (5%) [T8] did not present data about challenges or difficulties encountered.

RQ6: Which technologies were used in the development?

The main technology used was certainly the convolutional neural networks (CNN), which were present in 70% of the articles [T1, T2, T3, T4, T5, T8, T10, T11, T13, T14, T17, T18, T19, T20]. This is an artificial intelligence and machine learning technology, where it is a feed-forward artificial neural network, which has been successfully applied to the processing and analysis of digital images and facial recognition of both animals and humans.

Python was also a major player, being the most used programming language among the papers, 45% of the papers [T1, T2, T5, T10, T11, T14, T15, T19, T20] presented the use of Python or libraries (OpenCV for example), many of the articles mapped did not present the language used, but by the analyses probably in some step Python was used.

It is worth mentioning some of the technologies that did not appear in the papers as frequently, such as ResNet (Residual Neural Network) [T14, T17], PCA (Principal Component Analysis) [T6, T8, T9, T12, T15], Keras (open source neural network library written in Python) [T10, T11], Haar Cascade Classifier (Object Detection Algorithm used to identify faces in an image or a real time video) [T1], CUDA [T11] and Gaussian Filter / Pyramid [T5, T9].

RQ7: What methodology was applied?

All the analyzed works follow the standard steps of a recognition algorithm, apart from some variations, but basically it boils down to the initial phase responsible for finding the animal's face, or the part that you want to analyze, in the middle of the image, the next is where you must treat this face with pre-processing techniques such as rotate, scale, crop

and normalize. After that we proceed to the feature extraction phase where the images go through an extraction algorithm and the salient features are obtained and passed to the next phase, where they are compared with data from banks or test data, in the classification phase and finally the results are presented.

The variations found in the works were that some did some actions before treating the image, as in T16 for example where it is made a marking in the eyes of the animals, the T13 that performs an alignment of the face to avoid the angle variable that as seen in RQ4 is one of the factors that can cause interference in recognition.

6 I VALIDITY THREATS

During the construction of the systematic mapping, some choices are made by the author, such as in the application of the inclusion/exclusion criteria and in the extraction/interpretation of data from the selected studies. These decisions made by the author during the preparation of the mapping have a direct influence on the results obtained. But the risks were minimized because the results were presented and mapped by the author and the mentor/co-author in order to ensure the consistency and validity of the results.

7 I FINAL CONSIDERATIONS

The area of animal recognition is subject to a major advance, this technology was first applied to humans and reached the level of development we are today, now the trend is to use it in other ways while new ones are emerging to "replace", its benefits are clear, a way to collect data and identify a non-invasive way to the animal, in other words, without causing any harm to it, is the way we should start thinking for our sustainable development.

Through this mapping it was possible to notice a potential of practical application in this technology, its use in farms for data collection, its ability to identify individuals of endangered species, among other practical uses shows that its study is a logical path to follow.

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