monogut health

Optimal gut function in monogastric livestock

Validated machine-learning model to detect IUGR piglets

Authors: R. Ruggeri, G. Bee, P. Trevisi, C. Ollagnier

74th Annual Meeting of EAAP

Lyon, France - August 26th - September 1st, 2023

Centre de Congrès de Lyon

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 955374.

Abstract

Validated machine-learning model to detect IUGR piglets

R. Ruggeri[1,2], G.Bee[1], P. Trevisi[2], C. Ollagnier[1]

[1]Agroscope, Pig Research Unit, Rue de Tioleyre 4, 1725 Posieux, Switzerland, [2]University of Bologna,

Department of Agricultural and Food Sciences (DISTAL), Viale Giuseppe Fanin 40-50, 40127 Bologna, Italy,

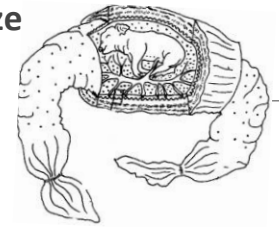
Intrauterine growth restriction (IUGR) is defined as the impaired development of the foetus during gestation. Piglets affected by IUGR have prioritized brain development as part of an adaptive reaction to placental insufficiency. This mechanism results in a higher brain-to-liver weight ratio (BrW/LW). The aim of this study was to develop a machine-learning model to predict the BrW/LW from a piglet's image and accurately diagnose IUGR. Two days (±1) after birth, brain and liver weight of each piglet were assessed with computed tomography scan (n = 299) or by weighting the organs after euthanasia (n = 65). A threshold value of 0.94±1 (mean + SD) was chosen to divide the piglets into NORM (BrW/LW < 0.94) and IUGR (BrW/LW ≥ 0.94). Videos of the piglets were taken using a RealSense camera. Selected frames of piglets were then used to predict the IUGR status through a convolutional neural network (CNN) developed in Python. The available data was split in two datasets. One dataset was used for training (80% of the data) and the other to validate the model and assess its performance (remaining 20% of the data). The CNN was trained five times and the results were expressed as average recall, precision and F1 score. Recall represents the percentage of IUGR piglets the CNN correctly predicted, over all the IUGR cases. Precision is a measure of how many of the IUGR predictions made were correct. F1 score is the harmonic mean of precision and recall. The CNN performed in the training dataset with a recall, precision and F1 score equal to 97%, 53% and 65%, respectively. In the validation phase, recall, precision and F1 score were reduced to 88%, 50% and 64%, respectively. The present results showed that the CNN was able to identify most of the IUGR piglets in both the training and the validation phase. However, 32% and 27% of the NORM piglets were classified as IUGR in the training and in the validation dataset, respectively. In conclusion, the model is highly sensitive in detecting the IUGR cases but precision could still be improved.

Acknowledgements: This project has received funding from the European Union's Horizon 2020 research and innovation program under grant agreement N°955374.

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 955374.

Introduction

1. Increased **litter size**

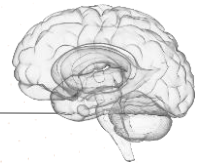


2. Increased exposition to **intrauterine growth restriction** (IUGR)

3. Low neonatal **survival rates** and long-term **growth** limitations

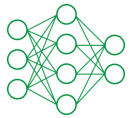
4. Inaccurate **diagnosis** due to the **absence of specific symptoms** and reliable **biomarkers**

5. Altered **blood flow distribution** to **preserve** cerebral functionality



6. Relative **increase in brain size** when compared to other organs

7. Gold standard to assess the degree of IUGR is the ratio between **the weight** of the **brain** and the **weight** of other **organs**



8. Develop a model to **predict the ratio** and **diagnose IUGR**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 955374.

Materials and methods – data collection study 1

311 piglets

birth weight (BtW)

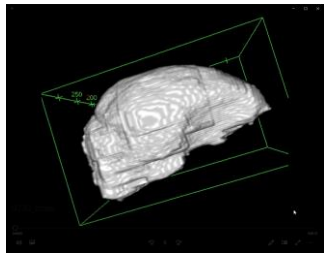
43 stillborn

268 alive

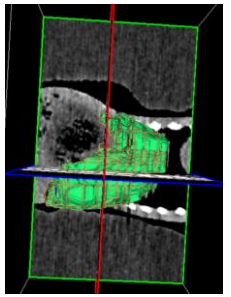
computed tomography scan imaging

30 euthanized

brain

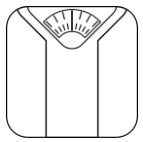


liver

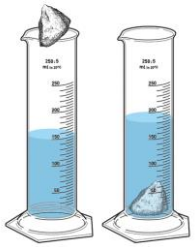


15 females

15 males



x



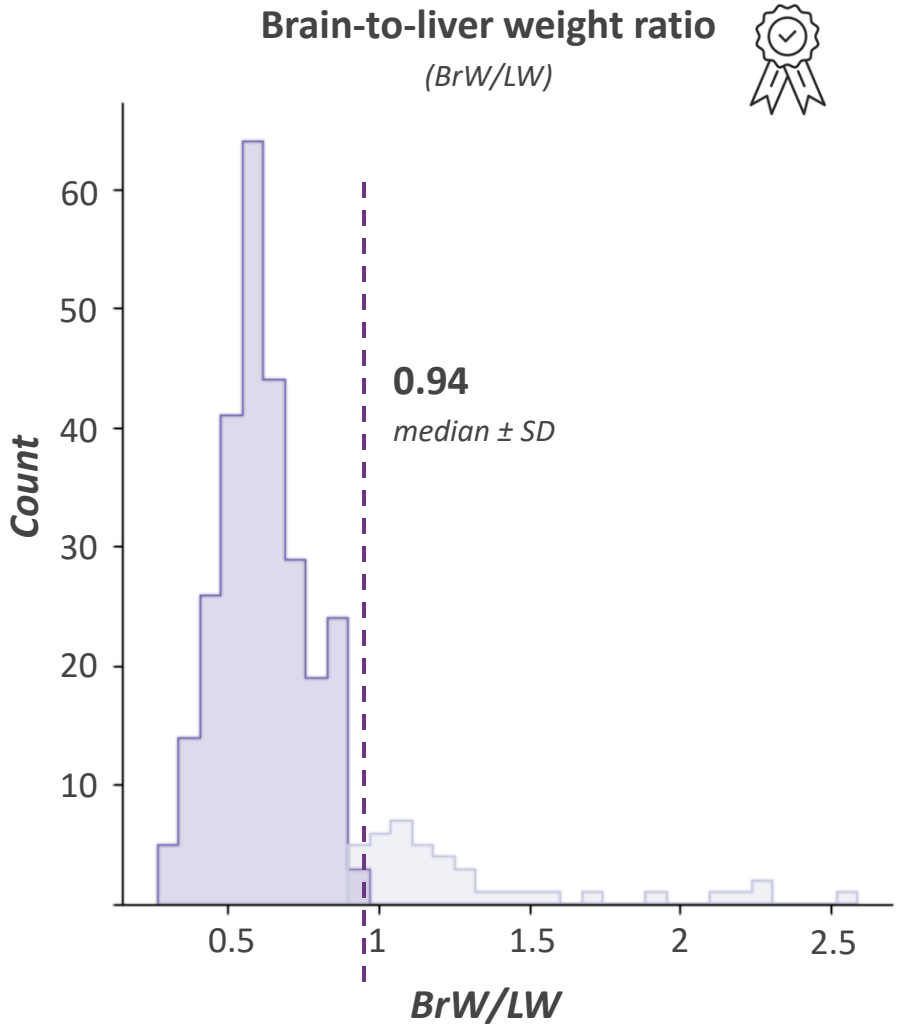
brain and liver density

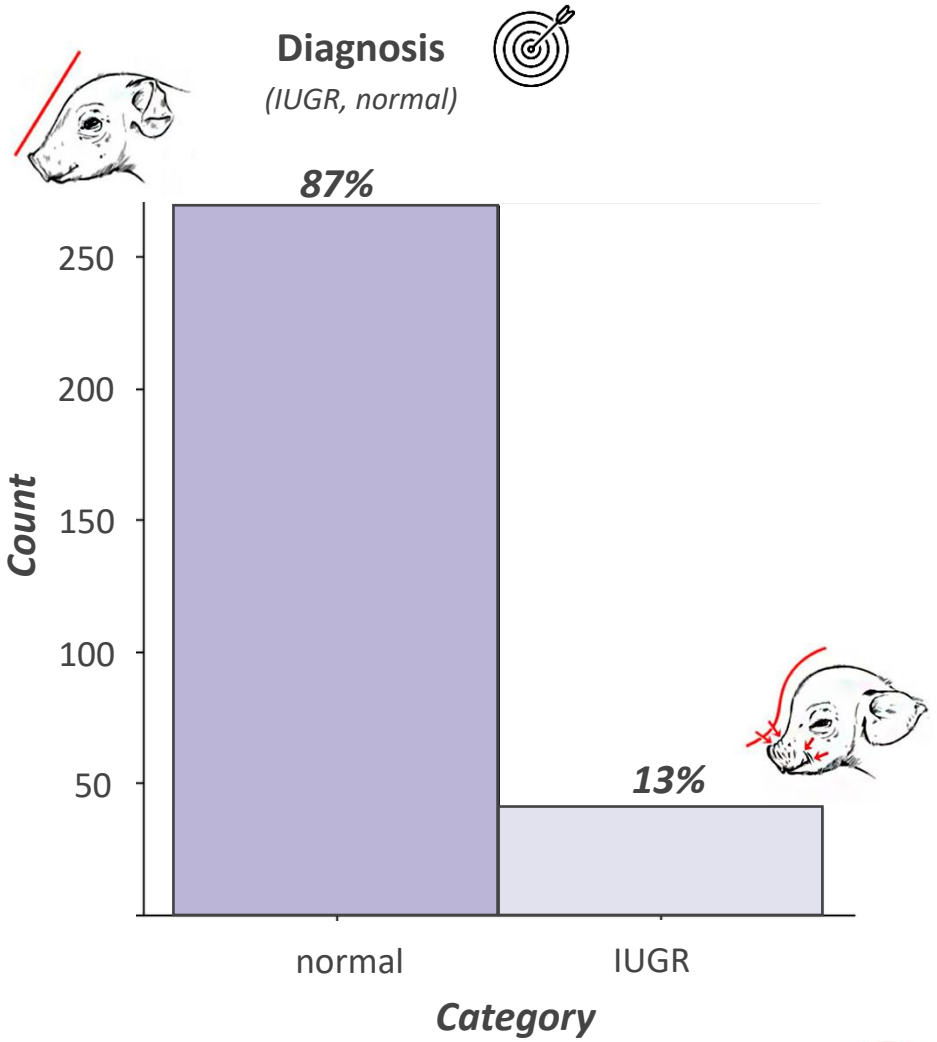
brain weight (BrW)

liver weight (LW)

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 955374.

Materials and methods – data visualization study 1





This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 955374.

Materials and methods – data collection study 1

311 piglets

43 stillborn

268 alive

3D imaging

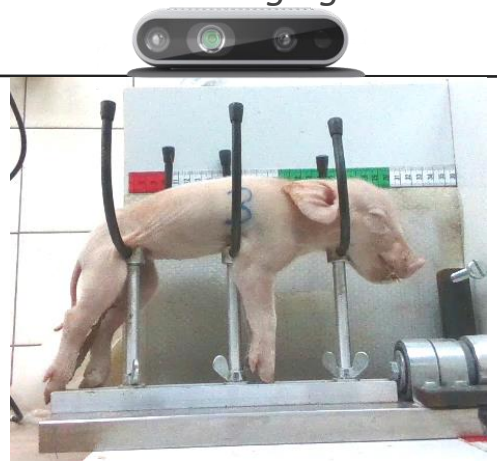
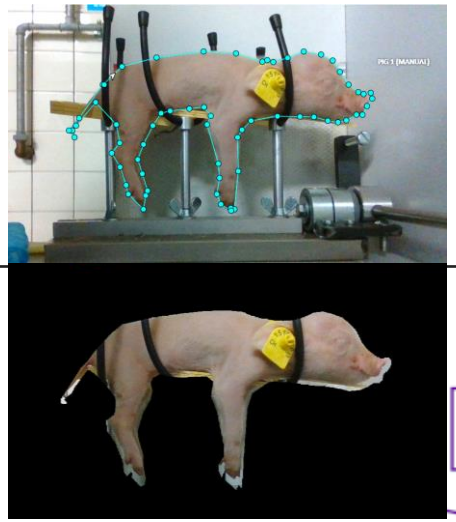
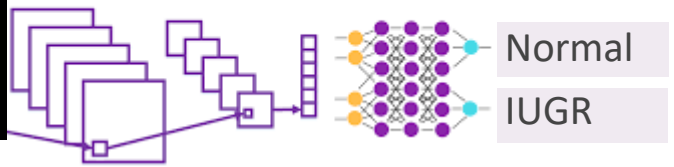


image segmentation

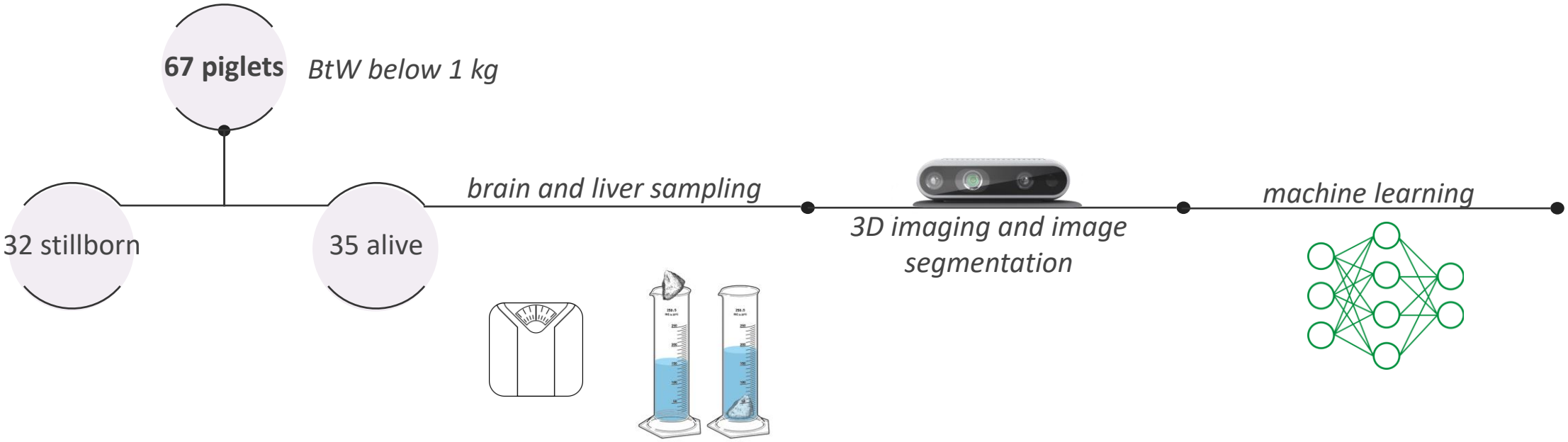


machine learning



This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 955374.

Materials and methods – data collection study 2

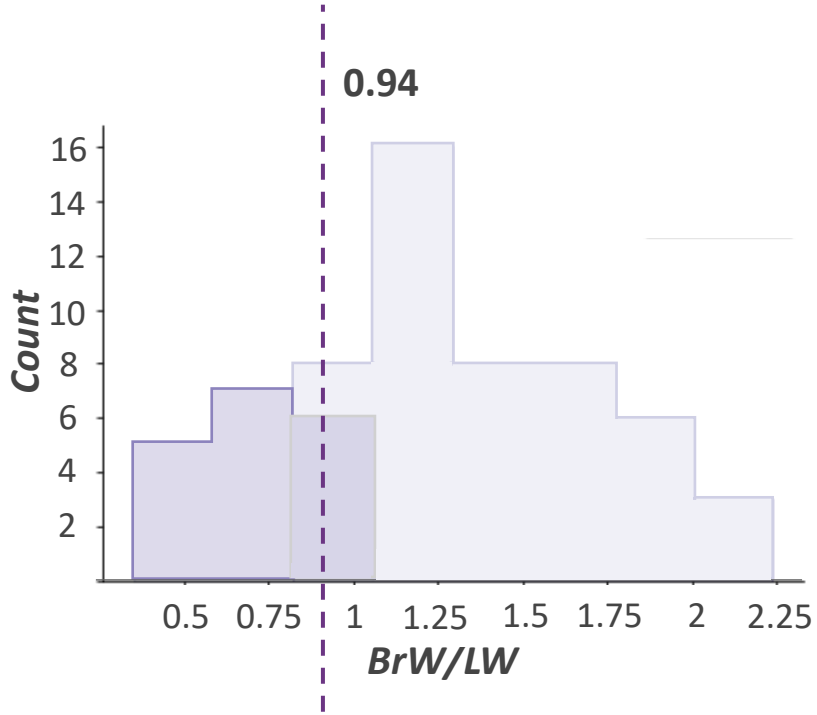


This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 955374.

Materials and methods – data visualization study 2

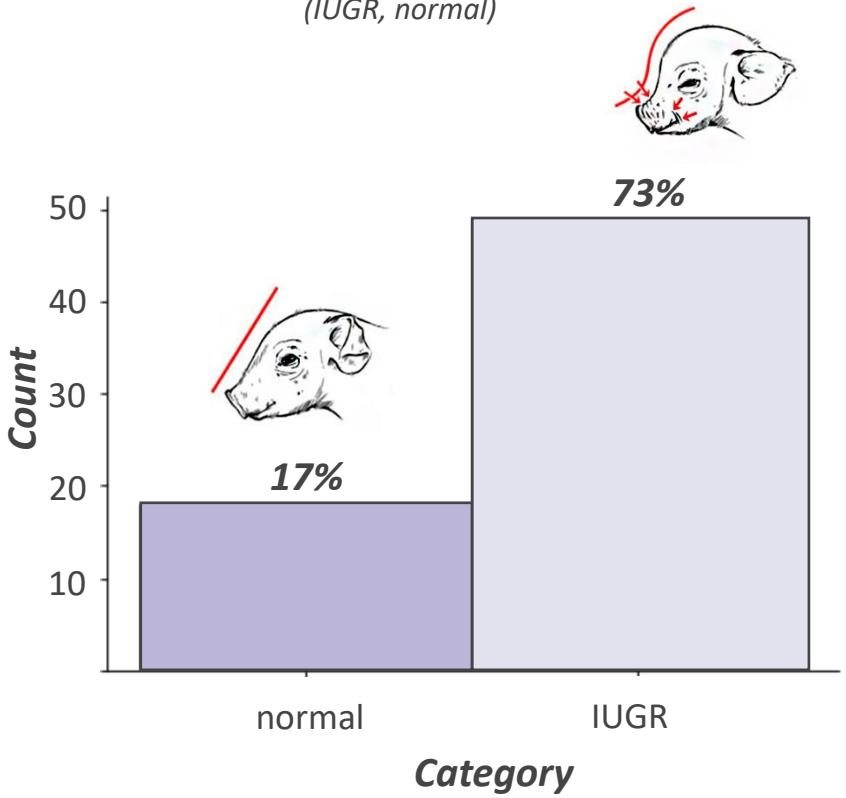
Brain-to-liver weight ratio

(BrW/LW)



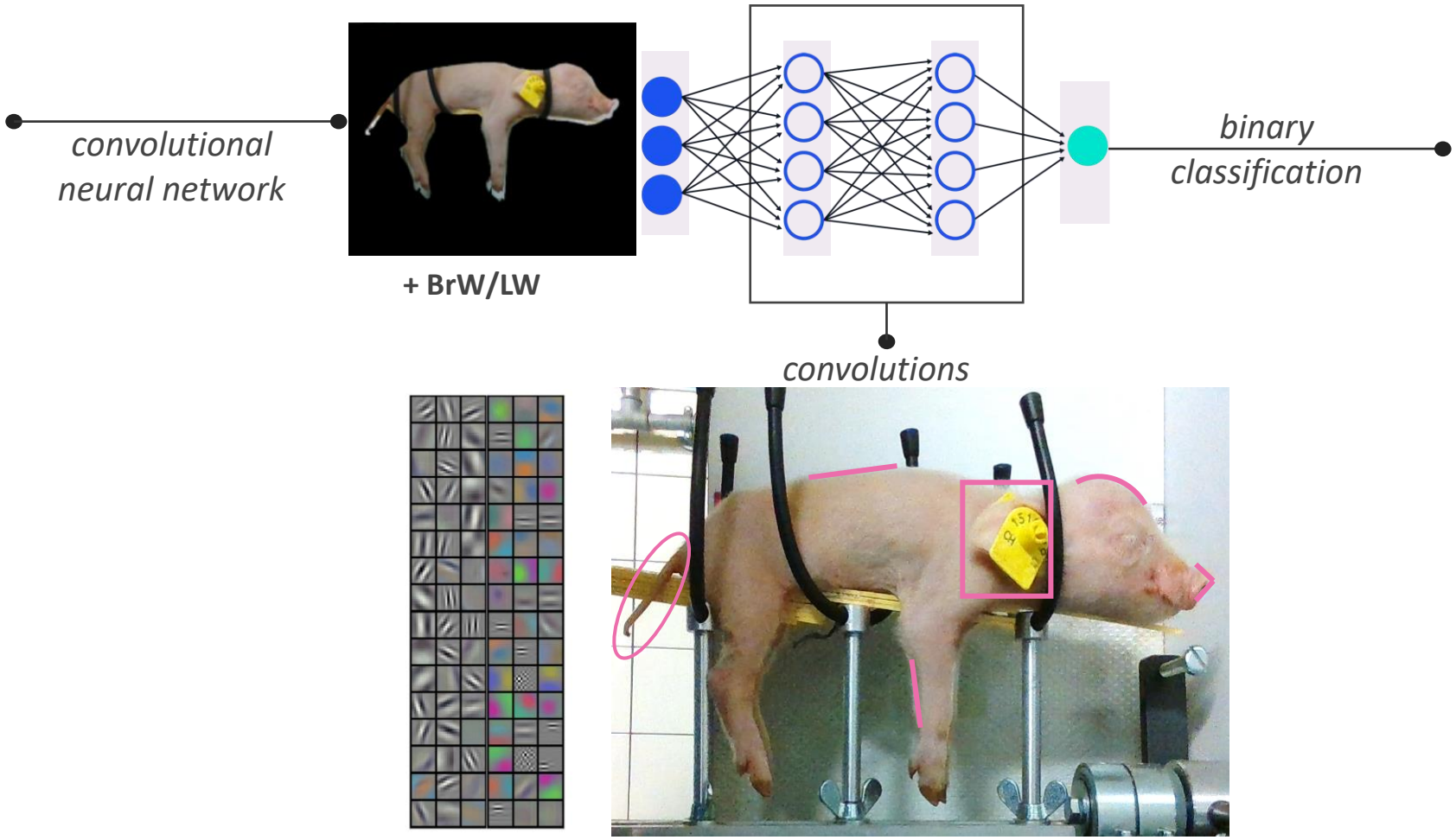
Diagnosis

(IUGR, normal)



This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 955374.

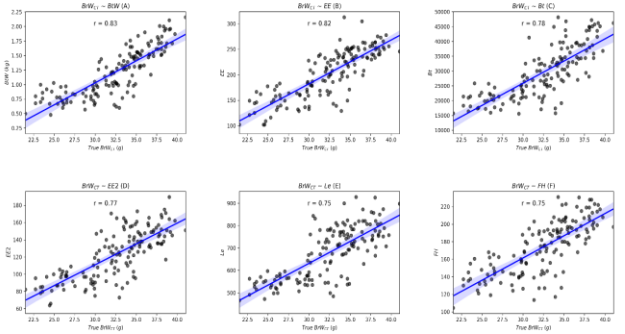
Materials and methods – machine learning



- ✓ ***Recall***: *detected IUGR cases on total IUGR cases*
- ✓ ***Precision***: *correct IUGR predictions on total IUGR precisions*
- ✓ ***F1 score***: *harmonic mean of recall and precision*

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 955374.

Materials and methods – regressions

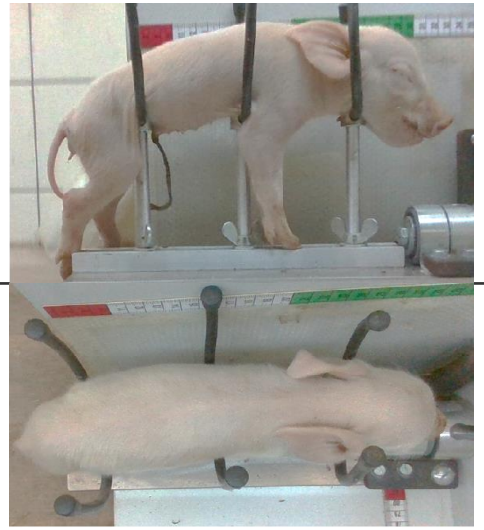


144 piglets

study 1

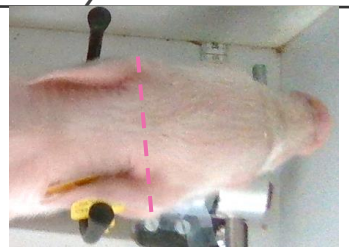
study 2

frame 1



frame 2

body measurements



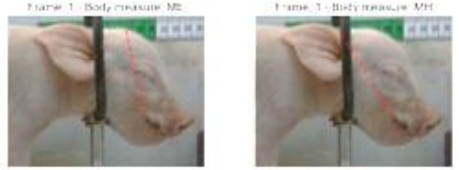
BrW

correlations

LW

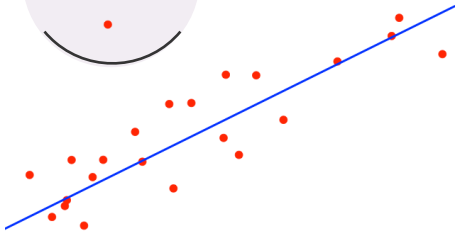
This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 955374.

Materials and methods – regressions

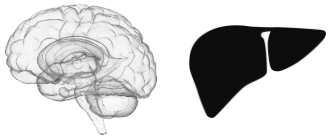


20 measurements

13 brain — *n = 1* — 6 liver



simple linear regression



Pearson correlation

≥ 0.70

multiple linear regression

BtW

$$BrW = intercept + a1 \times BtW + a2 \times EE$$
$$LW = intercept + a1 \times BtW + a2 \times L$$

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 955374.

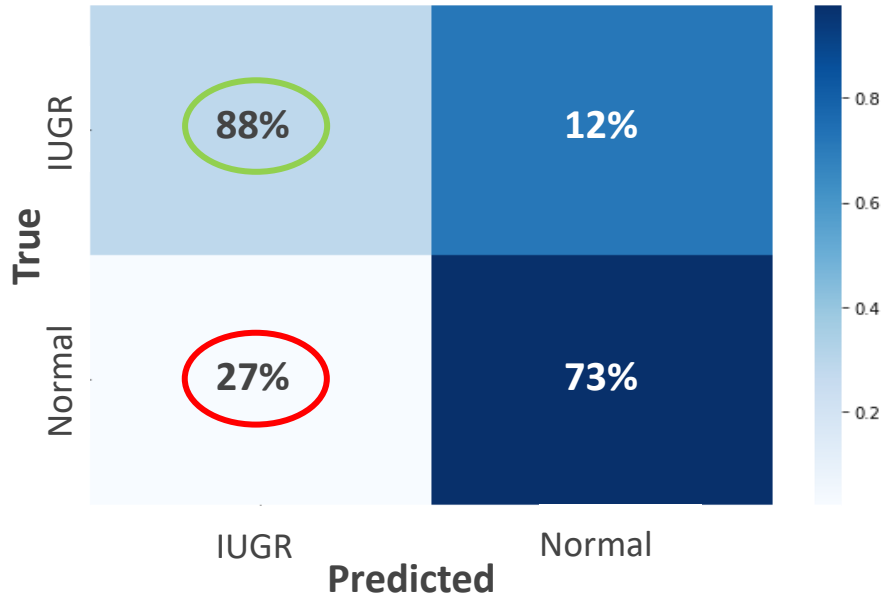
Results – machine learning

Training

- ✓ Recall: 97%
- ✓ Precision: 53%
- ✓ F1 score: 65%

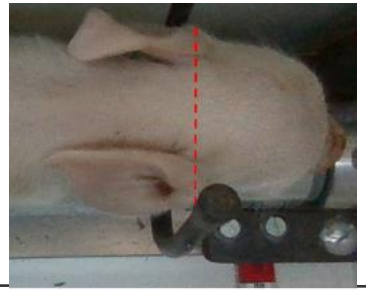
Validation

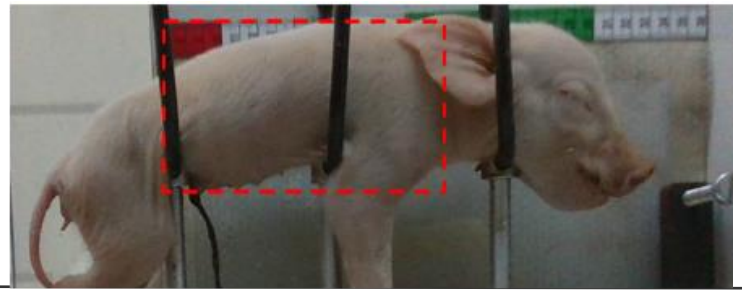
- ✓ Recall: 88%
- ✓ Precision: 50%
- ✓ F1 score: 64%



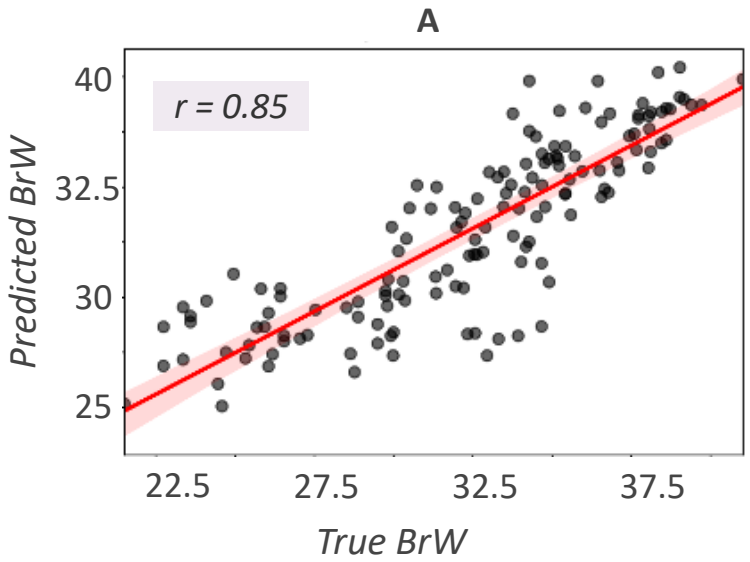
This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 955374.

Results – regressions

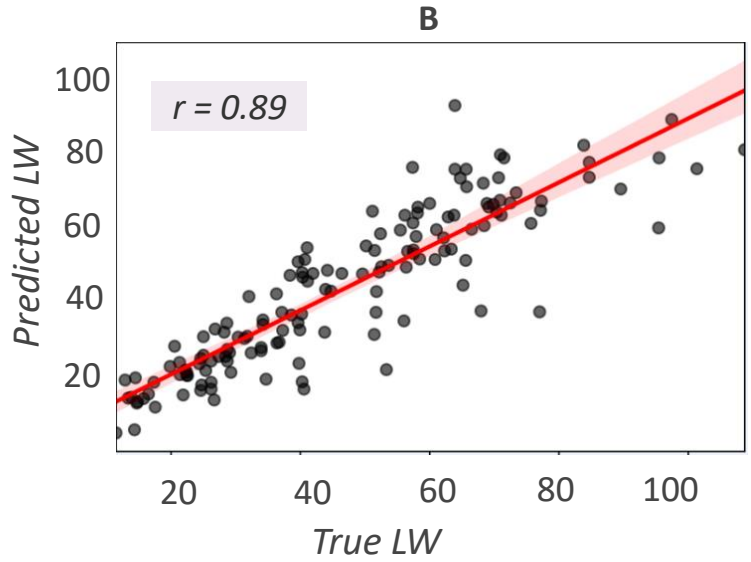




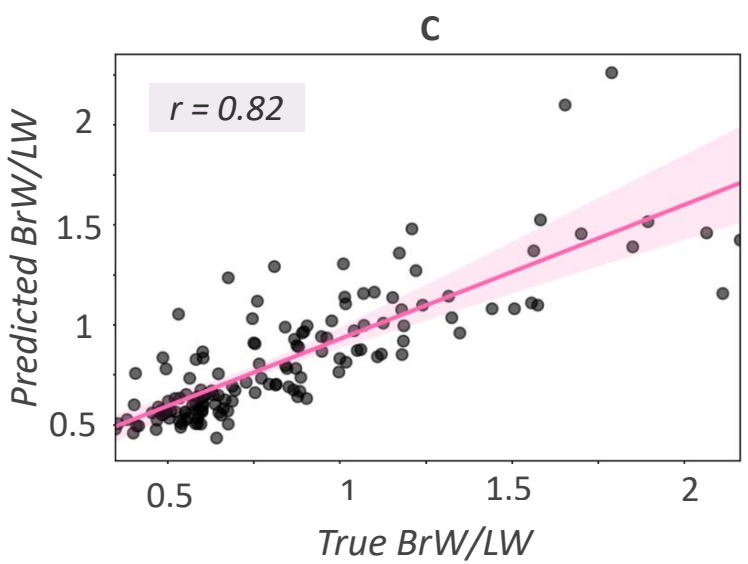
Correlation between the true and predicted BrW (A), LW (B) and BrW/LW (C)



Mean absolute percentage error: **6%**



Mean absolute percentage error: **17%**

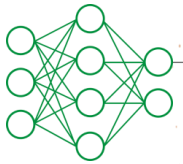


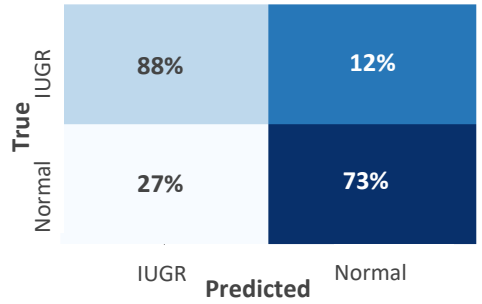
Mean absolute percentage error: **18%**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 955374.

Take home message

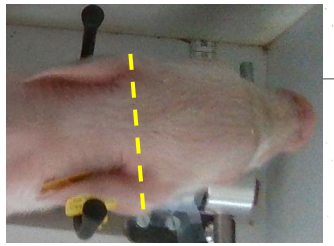
1. Convolutional neural networks can be used **to diagnose IUGR** in newborn piglets





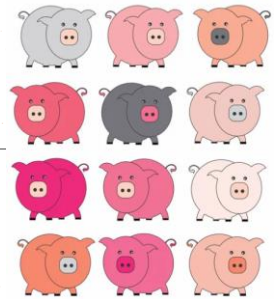
2. Our convolutional network is highly **sensitive** in detecting the IUGR cases (88%) but **precision** (50%) needs to be improved

3. Several morphometric traits can be used to **estimate** the **brain** and **liver weight** from images of newborn piglets



4. If the **relative brain weight** of a newborn piglet is below the **3%** of its **body weight**, the piglet can be diagnosed as **normal** (*Amdi et al., 2013*)

5. The brain weight **estimated** with our equations (error rate: 6%) can be compared with the **birth weight**, enabling a **non-invasive** and **accurate** diagnosis of normal piglets



6. Future studies should focus on **validating** these models **in larger populations** and exploring their **applicability in the field**

This project has received funding from the European Union's Horizon 2020 research and innovation programme under the Marie Sklodowska-Curie grant agreement No 955374.

THANK YOU

Do you have any questions?

Organisation

Name Roberta Ruggeri

Email roberta.ruggeri@agroscope.admin.ch

Website [ESR1: What are IUGR pigs? – phenotypic and metabolic differentiation - MonoGutHealth]

Agroscope

ALMA MATER STUDIORUM
UNIVERSITÀ DI BOLOGNA

monogut health

Optimal gut function in monogastric livestock

This project has received funding from the European Union's Horizon 2020 research a
innovation programme under the Marie Sklodowska-Curie grant agreement No 95537