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How to prevent the worst case: Scalding of sensible pigs; automated procedure for detection of onset of death of slaughter pigs in industrial plants (Check Signs of Life) (#365)

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Introduction

For legal and ethical reasons it has to be prevented that potentially sensible pigs could undergo painful further processing after bleeding. European abattoir operators are obliged to verify the absence of signs of life (SOL) prior to further dressing and scalding. German legislation moreover requires absence of any movements at this step of the process. With higher slaughter speeds and level of industry automation there is an increasing risk that failures at stunning and bleeding will lead to the worst-case scenario described. An automatic detection method could be the solution considering the rarity of cases. In a preceding project (2012-2015), funded by the Federal Ministry of Food and Agriculture, we used hot-water spraying (65°C, 4s) to head and front legs as a diagnostic test several minutes after bleeding. Subsequently short video sequences were recorded for each pig and analyzed in real time by custom software based on Optical Flow, an image processing tool (OF-system). Checking this system on 20.589 pigs as well after electric as after CO_2-stunning we were able to detect 68% of those showing active movements. Based on a side result of this project, i.e. that 100% of the pigs with remaining brain function at time of scalding had shown repeated mouth-opening already before reaching the water spray, in the actually described project (2016-2018), supported by funds of German Governments' Special Purpose Fund held at Landwirtschaftliche Rentenbank, we aimed to refine the system. To reach a higher sensitivity we now used visual and 3D-data of the animal bodies moving toward scalding to non-invasively assess SOL by software analysis in realtime (3D-system).

Methods

The developed 3D-device, now called SOL-3D, registers movements of the pigs being processed towards scalding by one or two 3D-sensors in series, monitoring the pigs over a processing distance of 3 m and approximately for 30 seconds in total. An Artificial Intelligence (AI) in the central unit analyses the position data of the suspended pigs in real time (**figure 1**). The AI was first trained by previously collected reference data to detect - while pigs pass the sensors - opening of the mouth or movements of the head, body or forelegs, which could be identified as active movements, not caused by e.g. processing on the rail (n=3.600 pigs, CO_2-stunning). Further reference data collected by simultaneously performed veterinary assessment at site were subsequently used to refine the algorithm (supervised learning) and continuously improve the sensitivity. The investigations were performed during routine slaughter procedures (line speed: 300 and 400/h). Between August and December 2016 15.390 pigs after CO_2-stunning were included in the investigation using as well 3D- as OF-system at the same time and comparing to direct observation (**study a**). In the subsequent tests in a plant using electric stunning, between May and September 2017 we analysed 12.730 pigs by OF-system and 12.813 by 3D-system against direct observation, in most cases simultanously. To prevent negative interaction between the systems, the 3D-system in this plant was investigated 70 s later than the OF-system (**study b**). From March 2018 on we checked the 3D-system in a third plant on another 15.274 pigs after CO_2- stunning (**study c**). Additionally we developed graphic surfaces for real time display, retrospective daily analysis and connection to the plants controlling system.

Results

Table 1 shows the results of **study a**, both detection-systems compared after CO_2 stunning. The 3D-system (here with 2 sensors) reached a higher average sensitivity (89% and 86% respectively) than the OF-system (68%), although the water spray of the nearby OF-system sometimes lead to pollution of the 3D-sensor. In **study b** after electric stunning the sensitivity of the OF-system was 79%, the positive predictive value 72.4%. Average sensitivity (80%) and positive predictive value (75.3%) of the 3D-system (here with one sensor) were slightly higher (see **table 2**). In **study c** (CO_2-stunning) the one sensor 3D-system reached a sensitivity of 92%.

Conclusion

To perform further dressing or scalding of pigs "only once the absence of signs of life of the animal has been verified" (Council Regulation (EC) No 1099/2009, Annex III, 3.2) presents a challenge to the business operator with regard to high slaughter speed and low presence of staff at this point of the slaughter process. So far automatic tools exist only to check bleeding, but we are the first, having brought into practice an automatic system to monitor the onset of death by cessation of any active movement in realtime on the slaughter line. Using AI on 3D sensor data we achieved a high precision, althought improvements are still possible. Limiting factors may also be plant specific (e.g. short recording time possible, rapid body rotation). The system requires some input at the beginning, because the AI has to be trained to the specific situation at site, but afterwards there will be a robust tool, as the first three systems created within the project are used for over a year now in daily operation at slaughter.

Notes

Optical flow (OF-)system			Non-invasive 3D-system					
			Sensor 1			Sensor 2		
day	pigs (n)	sensitivity (%)	pigs (n)[1]	sensitivity (%)	measurement duration (s)[2]	pigs (n)[1]	sensitivity (%)	measurement duration (s)[2]
1	1.981	70%	1.881	82%	18.4	1.815	89%	24.4
2	1.923	100%	2.031	75%	25.7	1.938	100%	19.1
3	1.363	67%	1.429	100%	18.5	1.465	89%	35.7
4	1.473	64%	1.488	100%	20.3	1.503	67%	18.4
All/Ø	**6.740**	**67.6%**	**6.829**	**89.2%**	**20.7**	**6.721**	**86.1%**	**24.4**

[1] different numbers of animals according to different counting mechanisms

[2] average duration, variation of measurement duration due to e.g. line stops

Table 1

Table 1: Sensitivity with regard to detection of signs of life in pigs before further processing (4 study days, CO_2-stunning)– System using optical flow software compared to non invasive 3D-system with two sensors, sensitivity by sensor

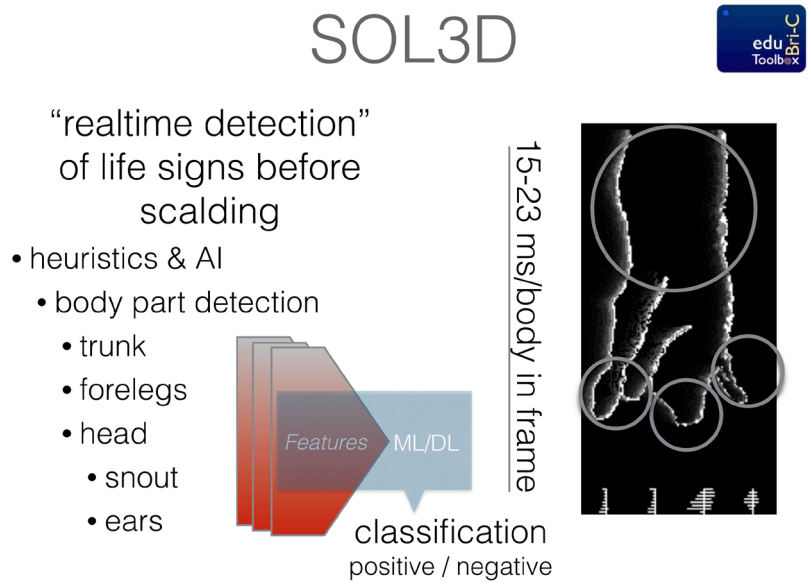

Figure 1

Schematics of the steps to classify the pigs data in realtime

Notes

Day	Pigs (n)	Sensitivity (%)	Positive predictive value (%)
8	1.391	79%	73%
9	1.245	67%	67%
10	1.415	88%	100%
11	1.160	78%	78%
12	780	100%	~~25,00%~~[3]
14	2.108	73%	73%
15	979	60%	56%
16	1.422	75%	75%
17	2.313	100%	80%
Total / Ø	**12.813**	**79.9%**	**75.3%**

[3] data could not be calculated due to missing numbers (mist)

Table 2 Table 2: Sensitivity with regard to detection of signs of life in pigs before further processing (9 study days, electric stunning)– non invasive 3D-system with one sensor

Notes