Development of an autonomous roving data collection platform for caged poultry production

T. G.M. Demmers[1], P. Norman[3] and Q. Tong[2]

[1]*Royal Veterinary College, Animal Welfare Science and Ethics, Hawkshead Lane, North Mymms, Hatfield, AL9 7TA, United Kingdom*
[2]*Department of Agricultural Structure and Bioenvironmental Engineering, College of Water Resources and Civil Engineering, China Agricultural University, Beijing 100083, China*
[3]*Ross Robotics LtdRuscombe Lane, Unit 1 Tavistock Industrial Estate, Twyford, Reading, RG10 9NJ, United Kingdom*
tdemmers@rvc.ac.uk

Abstract

The Chinese poultry industry continues to use cages for growing both broiler and layer chickens in most commercial facilities with no plans to ban their use in the immediate future. In contrast, cages have been banned and are being phased out in Europe. In particular, broilers are and have been kept in large flocks on a littered floor. Both systems however, do have issues related to indoor environment, health and welfare. Various precision livestock farming (PLF) inspired systems have been developed to better monitor and thus improve the climatic conditions for floor based poultry systems (RoboChick, Octopus, ChickenBoy)

For the caged housing system, a large consortium of Chinese and UK industry and academia developed a dedicated autonomous data collection platform. The data platform combines robot technology with advanced sensors and indoor environmental management using real-time monitoring to maintain the best environmental and animal welfare conditions, improving production yield, and providing early detection of poultry disease and minimal anti-biotics use.

The prototype autonomous navigating robot was developed in the UK and fitted with the sensors and datalogging systems. A bespoke user interface was developed to map the environment the robot would be operating in and allow assignment of monitoring positions. The navigation systems were tested in a caged poultry facility in the UK and proven to be highly accurate and reliable in positioning the robot and avoiding obstacles essential for autonomous operation. The jointly developed monitoring systems were integrated with the platforms software and bespoke cloud based databases.

Keywords: poultry, robotics, environment

Introduction

China is the world's largest producer of eggs and a big chicken grower (FAOSTAT, 2015). Over the years there has been a steady shift in both the egg and poultry meat sector from small to medium sized local production facilities too large to very large integrated farms. The latter are typically owned by large often vertically integrated companies. Contrary to Europe, most houses in China/Asia are cage based for both poultry meat (broiler) and egg production. In common with most poultry houses worldwide, only a few monitoring devices are used for environmental control. The installation of numerous devices in the multi-tier caged housing common in China, is unlikely to reflect the whole environment from floor level to the top tier of cages and will be unaffordable. Secondly, sub-clinical and clinical disease (Zhuang et al., 2014) affect animal and gut health, reducing food conversion and welfare and increasingly cause huge financial losses .

To improve the health and welfare of the birds and environmental conditions in caged facilities, an autonomous robot moving between the cages and sampling the environment at multiple levels and observing the birds could provide the necessary data (Demmers, Dennis, Norman, Butler, & Clare, 2019; Dennis, Abeyesinghe, & Demmers, 2020). The robot collected data will give a 3D view of all parameters including temperature, humidity, air velocity, CO_2. On-board cameras will allow visual assessment of the conditions in the cages. Importantly the development of an automated version of a VOC sampling & sensing system will allow early detection of diseases to be possible for the first time. Compilation of the data gathered will not only detect diseases before symptoms are seen, but by cross-reference allow predictive modelling. Thus, for the first time the poultry farmer could potentially reduce sickness in birds, reduce the use of anti-biotics/treatments; improve bird welfare, production yield and rebuild consumer confidence in the quality of his product.

Material and methods

Autonomous navigation platform

For the purpose of the project a prototype robot, capable of autonomous navigation through a caged poultry house was designed and developed by Ross Robotics Ltd, based on the requirements provided by the farm managers and the research team. The navigation systems tested in a small scale layer facility at Harper Adams University and a commercial poultry farm. The robot's navigation system consist of a LIDAR system. The navigation software development was based on the existing autonomous roving platform (Ross Robotics Ltd). The robot has a fully automated docking and recharging station. The sensors and cameras are mounted on a 3m high mast with flexible spacing and their data acquisition and control systems are integrated into the base of the robot.

Sensor systems

The environmental sensors were selected based on suitability, size and price. 3D Sonic anemometers (Wind Master, Gill Instruments Ltd) were used to measure air speed and direction; PT100 and conductivity probes for temperature and humidity (HC2 probe, Rotronic Ltd); electrochemical diffusion sensor for ammonia concentration (DOL53, Drager GmbH); Non-dispersive infrared absorption for Carbon Dioxide (CoZir-A; GSS Ltd); Optical sensor for the dust concentration and size fractions (OPC-N3; Alphasense Ltd) and a spectroradiometer for the light intensity (SM2000; Optimum Corp.). All sensors were powered and data logged from a purpose built data acquisition system based on a Raspberry Pi model 4B combined with a data acquisition processor (STM32; STMicroelectronics).

In addition, a camera module, based on a small form PC (X86 UP Board; UP Ltd) recorded images of the birds in the cages using 4 video camera (xcg-CG240C; Sony Ltd) and lens (FL-DD0614A-2M; Ricoh GmbH). Data collected were transferred during charging of the robot to a dedicated data base prior to analysis using AI technology (outside scope of paper).

Figure 1: Autonomous navigating robot inside access corridor poultry facility with camera and wind speed sensors fitted (Ross Robotics) and or the right the CAU built platform inside a layer house in Beijing District, China.

The collected real time data, time and location stamped by the robot during roaming the building are transferred wirelessly to a server (host pc) and/or transferred during recharging to a bespoke database (MS access) build by the Chinese Agricultural University (CAU) and hosted in the cloud.

Delays in the project due to the Covid19 pandemic and budget reductions imposed by the funding body, forced Ross Robotics to withdraw from the project. A simplified version of the robot was built by CAU and used for data collection, incorporating the original sensors, cameras and data acquisition modules.

Building sensor systems

The building at the commercial layer farm in China used for the robot trials (Beijing DeQingYuan Agriculture Technology Co) housed 110,000 birds two floors each with 6 rows of cages (see figure 2). The house is tunnel ventilated with air inlets at the gable end and along the sides of the building (minimum ventilation) and the fans all at the opposite gable end. There are only a few sensors available for monitoring and controlling the environment located at 3 points in the building (see figure 2). All sensor are fitted in one plane across the building.

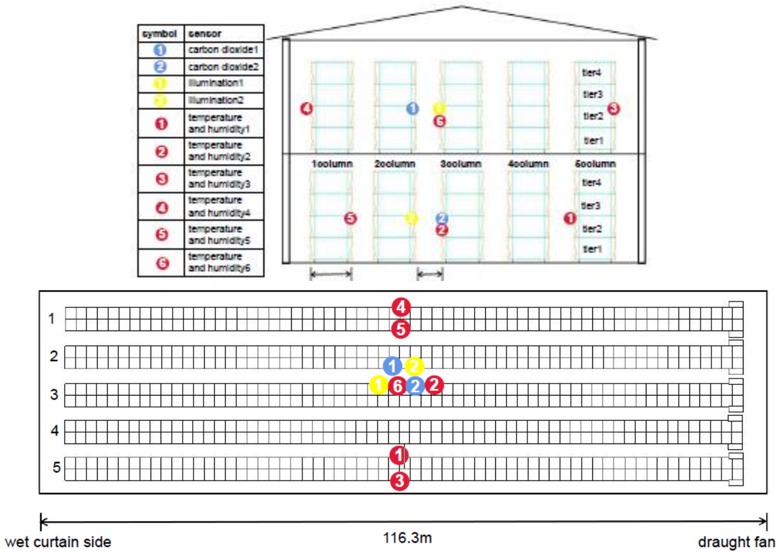

Figure 2: Sensors and sensor location in the layer farm at Beijing DeqingYuan.

Results and Discussion

The navigation and stability of the robot was tested in the access corridor of a commercial farm (100m length) and a small caged bird research facility (25m length). The robot was able to navigate both environments with great accuracy (return to set waypoints, error within 0.025m). However, due to reflections from the walls and objects, the main lidar system detected "ghost" objects and the robot was unable to proceed at certain locations. The addition of a short range forward facing camera and changes to the software solved this issue. The bespoke user interface worked well during training of the navigation system in the research facility.

The alternative robot uses a very similar navigation system, but has fixed waypoints based not on coordinates but on markers in the corridors between the cages. Using this system, data were collected from early December 2021 till the 29th of December 2021 (interrupted for Winter Olympic Games).

The data shown in figure 3 are the temperature, humidity, carbon dioxide, ammonia and particulate profile for the building at the ground floor. The data for the farm sensors at the time are given it table 1.

The farm temperature sensors and robot profile match well for sensor 5 (23.8 C v 23.8 C) but are under reading on the robot for location 1 and 2 in this instance. However, it is also very clear that over the length of the building the gradients for all measured parameters are even larger. For temperature the range is from 20.1 to 24.9 C for locations nearest the front and fans respectively. Similar gradients are observed for carbon dioxide (2900 – 3800 ppm) and ammonia (7.3 – 14.3 ppm). As expected the gradient is less for air speed (0.25 – 0.3 m.s^{-1}).

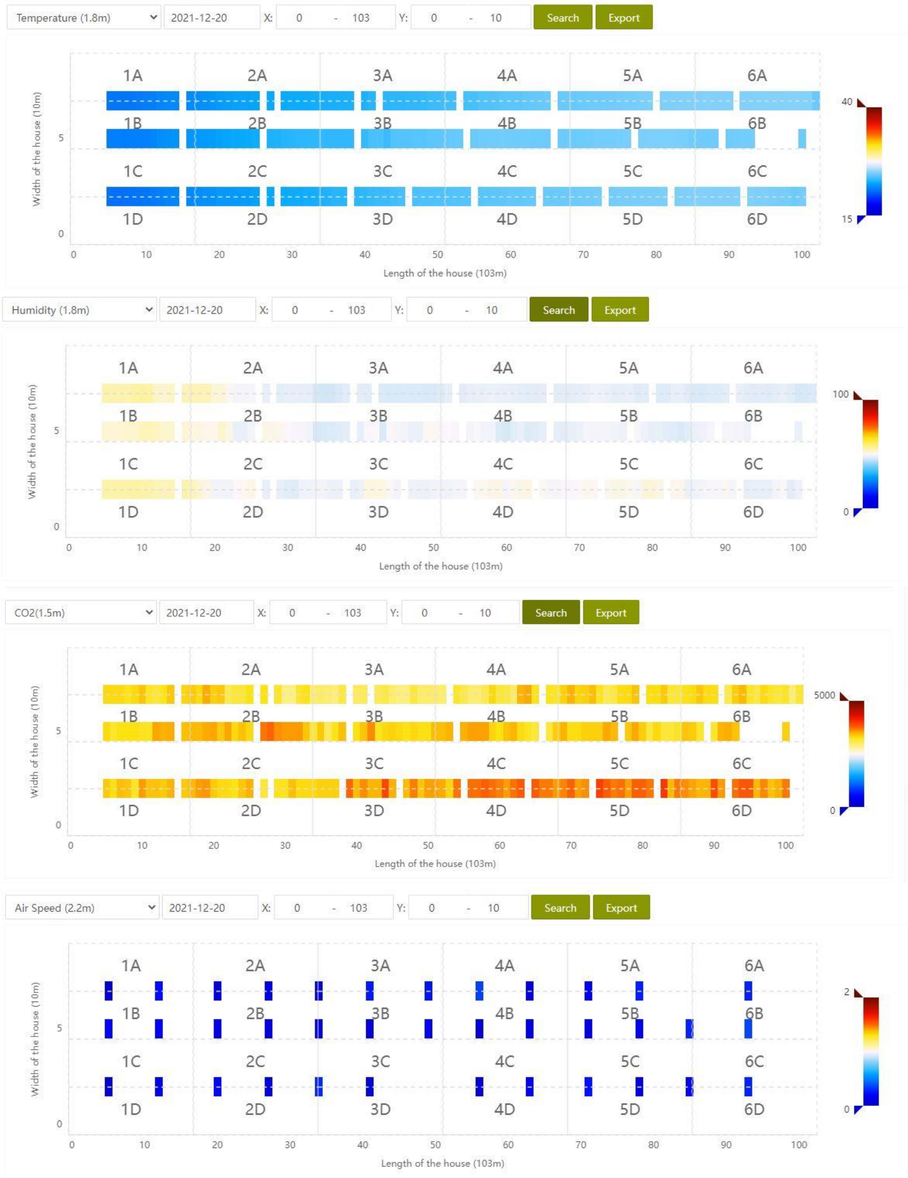

Figure 3: The temperature, humidity, carbon dioxide and airspeed profile as measured with robot at the layer farm on 20 12 2021 from 8 till 10am between rows 1-2, 2-3 and 4-5. The air speed is only give for the locations where the robot was stationary.

The data are currently being analysed and real time advice on the environmental conditions in the houses is being provided to the farm manager on a daily basis. Ultimately, the aim is to understand better how to can manipulate the environmental management system (fans, cooling, heating) to optimise the environment in the complete building to maximise the welfare for all birds rather than a small section in the centre of the building. The robot data are essential in this process. Additionally, the camera system on the robot will provide detail on the behaviour of the birds as well as the number and location of death birds, whereas a volatile organic component sensor capable of detecting the unique "finger" print for specific poultry diseases (Coccidiosis for instance) will add the health status of birds in regions of the house**.** Taking all data together we will be able to create a scoring system that will be used in the end user Dashboard.

All the data will be reported to the farm manager in the form of "tickets" reporting daily issues and through and interactive dashboard created for the data received.

Table 1: The temperature, humidity, carbon dioxide and light measured with stationary house sensors at the layer farm on 20 12 2021 at 9am.

Location	Temperature [C]	Humidity [%]	CO_2 [ppm]	Light [lux]
1	25.9	55.3	3580	xx
2	27.0	54.8	3125	xx
3	26.9	60.2		
4	25.6	59.8		
5	23.8	59.3		
6	27.4	56.8		

Conclusions

The developed autonomous roving data platform(s) can navigate the caged poultry house environment effectively and accurately collecting data from a range of environmental, welfare and health sensors at known locations throughout the house.

The data will enable optimisation of the environmental conditions in the house using an interactive system of notifications and an end user dashboard.

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