An ASABE Meeting Presentation

Paper Number: 077022

FeederAnt
- An autonomous mobile unit feeding outdoor pigs

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**Written for presentation at the
2007 ASABE Annual International Meeting
Sponsored by ASABE
Minneapolis Convention Center
Minneapolis, Minnesota
17 - 20 June 2007**

Abstract. *Small robots and the concept of decentralized animal husbandry make it possible to renew the principles of organic agriculture. The farm animals will be able to use the same type of housing and are placed integrated with the fields. This is expected to achieve a better utilization of nutrients and a better survival rate for useful insects and micro organisms. The small fields are flexible and could fit to the variation in soil structure topography. This type of precision agriculture has the possibility of increasing biodiversity.*

The paper presents the concept of an autonomic feeding system for outdoor piglets. Initial results are presented using a remote controlled feeding unit (a prototype of the FeederAnt) to feed several pens with piglets. The FeederAnt drives into the grass paddocks twice a day and position itself in a new location for each feeding. This will help to distribute the manure from the animals evenly over the grass paddock to prevent point leaching of nutrients. The FeederAnt replaces many stationary feeding tables and reduce the amount of daily manual feeding routines. Further, it is expected that the problem with vermins will be solved since no feed residues will be left within the pens..

Keywords. Robotics, automatic feeding, Animal Nursing Robotics, agriculture, traceability.

Introduction

Vision

Small robots and the concept of decentralized animal husbandry make it possible to renew the production structure of organic agriculture. All farm animals could use the same type of housing, which are located and integrated with the fields. This is expected to achieve a better utilization of nutrients and a better survival rate for useful insects and micro organisms. The small fields are flexible and could fit to the variation in soil structure topography. This type of precision agriculture has possibility of increasing biodiversity (Kirchman & Thorvaldsson, 2000; Buchs, 2003).

The farm animals should be envisioned as an integrated part of the crop rotation, performing the soil preparation, collecting crop residues after harvest and distributing the manure evenly over the grass paddocks. The distance from the housing unit to the field is short and the handling and application of the deep litter is easy for e.g. small animal and plant nursing robots. The housing unit could be used for pigs, calves and poultry in a rotation, which make the system flexible and reduce the risk of disease. New technologies will help rationalizing the animal management by making it easy to use wireless networks for control systems and develop autonomic self-propelled nursing robots.

Background

According to Andersen *et al.* (2005), the organic agriculture of today is not principally far from the conventional cropping system with its large fields of monocultures, large stables with slatted floors, plant nutrition based on the use of sludge as well as the heavy demand for fuel energy. The vision and challenge in terms of developing the organic agriculture in the next decade will be to introduce innovative technologies to promote a mixed agricultural, natural and cultural landscape with smaller production units comprising small fields and a livestock system in close connection to these fields. This new organic agriculture interferes significantly with the current management system: Centralized production units are replaced by small units placed decentralized in close connection to the fields. For example, cultivation carried out by large machines working deep in the soil or harvest carried out by large combine harvesters, which are specialized to operate only a few weeks per year and with limited possibilities of utilizing other parts of the plant than the grain, prompts the development of increasingly larger production units and machinery. This trend could successfully be replaced by small autonomous robots with increased flexibility and well fitted for uneven fields and different types of soils. Continuous livestock production will be replaced by seasonal production with farrowing pigs in the spring and the offspring slaughtered in winter, which will minimize the load on the paddocks and reduce the need for roughage outside the growing season (Andersen *et al.* 2005). Further seasonal production is expected to lower the leaching losses seen during wet winter periods as shown by Williams *et al*. (2000) and Eriksen & Kristensen (2001).

An increasing number of pigs are being kept outdoors in Europe in response to consumers' demand for naturally raised pigs (Watson and Edwards, 1997). Outdoor pig production has benefits in terms of animal welfare, allowing the animals the possibility to conduct natural behavior, and achieve low costs of buildings and equipment (Deering and Shepherd, 1985). On the other hand, there may be environmental costs resulting from high feed consumption (Larsen and Kongsted, 2000), losses of nitrate to aquifers (Eriksen, 2001), ammonia volatilization (Sommer et al., 2001) and atmospheric nitrous oxide emission (Petersen et al., 2001). These losses contribute to global warming, acid rain and the eutrophication of natural environments (Eriksen *et al.* 2006).

As mentioned, pigs on pasture impose the risk of leaching of nutrients from "hot spots" (Eriksen & Kristensen 2001). The hot spots occur when the feeding place is located in the same place for too long time, resulting in increased waste of feed and because the pigs defecate and urinate on their way from the sleeping nest to the feeding place (Eriksen & Hermansen, 2005). The pigs are social animals and prefer to eat together. In situations of lack of feed or too little feeding space, the pigs of lower rang order will grasp a mouth full of feed and move away, increasing the risk of feed waste too, and the lack of feed space will result in uneven access to the feed.

The above description of outdoor pig production raises a number of challenges to be met. Today, the daily transport of feed by use of conventional tractor hauled wagons is time consuming and stresses the soil structure by compaction. Further, the manual operation of feeding is stressful and labour intensive and may have a negative effect on the motivation of employees, especially under bad weather conditions. The feeding tray is stationary for long periods, which raise problems with uneven distribution of the faeces and urine in the pens. Secondly, this causes an increase in leaching and denitrification of the nitrogen, which is the most limiting crop production factor in organic farming (Hermansen & Kristensen 2001). Mobile feeders may help to distribute the manure from the animals evenly over the grass paddock to prevent point leaching of nutrients. Further, mobile feeders may replace stationary feeding tables and reduce the amount of daily manual feeding routines. Also, it is expected that the problem with vermins will be solved since no feed residues will be left within the pens.

Aim

This paper presents the concept of a mobile feeding system for outdoor piglets. Initial results are presented using a remote controlled feeding unit (a prototype of the FeederAnt) to feed several pens with piglets. The aim of the present case study is to evaluate the FeederAnt in relation to the function, the distribution of manure and the behaviour of the pigs towards the mobile feeding unit.

Safety Emphasis

The concept of an autonomic feeding system for outdoor piglets eliminates today's adverse effects on the worker manually feeding the piglets from a tractor. The small feeding unit reduces the risk of fatal accidents by way of the reduced size and power compared to a tractor.

Material and Method

The Remote Controlled Feeder – The FeederAnt

The FeederAnt consists of two main parts: 1 – The pyramidal feeder with one 150 mm caster wheel in each corner; 2 – A remote controlled mobile unit placed in the center of the pyramidal feeder.

The Pyramidal Feeder

The pyramidal Feeder is built as a feed store placed in the middle of the construction and an upper part above four mangers, which are placed on each side of the feeder. There are two or three manger rooms at each side with space for one animal each. The pyramid shape should help the feed pellet from falling into the manger and prevent pellet cakes from being disposed the corners.

Figure 1. The FeederAnt used as pig feeder with space for 12 eating weaned pigs.

The remote controlled mobile unit

The remotely controlled mobile traction unit is mounted in the middle of the pyramidal feeder. The mounted unit consists of a vertical steel bar in each corner of the unit which traverses a fastening aperture on the pyramidal feeder. In this way, the mobile unit does not have to carry the weight of the full pyramidal feeder. Furthermore, it can freely position itself and thereby ensure a constant optimal ground contact.

The mobile unit is a direct spinoff from a project developing a small plant nursing robot called Hortibot (Jørgensen *et al.* 2006). The mobile unit consists of:

- 4 wheel modules from a commercial Spider ILD01 slope mower (www.spider-cz.com)
- 2 12 VDC 70 Ah Gel batteries coupled in series (www.exide.com)
- 1 central 1100 Watt 24 VDC P2ZX Permanent-Magnet Motor (www.atas.cz) for comment propulsion of the wheels

- 1 24 VDC Valeo 0291 with worm gear for common steering of the wheel angle (www.valeo-swf-motoren.de)
- 1 AX2850 Dual 120 SmartAmps per Channel, Brushed DC Motor Controller (www.roboteq.com) for controlling the motors for propulsion and steering
- 1 12 VDC M2-ATX 160W Intelligent Car Power Supply for stabilized power supply for control electronics (www.LinITX.com)
- 1 safety stop relay
- 1 transmitter Planar-N with two 2 axis joysticks and 3 on/off functions with pushbuttons and 1 CAN-BUS-receiver (www.nbb.de)
- 1 modified Hortibot Control Computer (HCC) with CANBUS interface described by Jørgensen *et al.* 2006
- The operating system of the HCC is an embedded Linux distribution, iComLinux developed by Cetus, Denmark (www.cetus.dk). See also Jørgensen *et al.* 2006

When the HCC has booted the FeederAnt, it can remotely be controlled by joysticks at the Planar-N transmitter.


Figure 2. Left – The remotely controlled mobile unit. Right – The remotely controlled mobile unit within the pyramidal feeder construction (see also figure 3 right)

Case Study – The paddocks and the grouping of the pigs

One climate tent (see figure 3) was divided into four rooms, each holding one group of slaughtering pigs comprising four animals. The climate tent was the pig nest and only used for resting. The tent was placed on an area of 13.2 m x 13.2 m of mussel shells placed on the ground, bedded with straw and fenced with 3 electric wires. The deep bedded outdoor area was divided into four sections, one for each room in the tent and group of slaughter pigs. From the deep bedded outdoor area the pigs had access to a grass paddock 6.6 m wide and either 140 m long or 73 m in length – see figure 3 & 4 displaying the layout. The paddocks were fenced with an electric gate functioning as the passage in and out of the paddocks in the end farthest off from the tent. The FeederAnt passed through these electric gates.

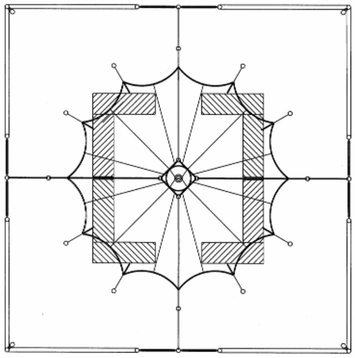


Figure 3. Left - Layout of climate tent for animals seen from above.
Right – The FeederAnt feeding the pigs seen from North East with the climate tent in the background

Each group of slaughtering pigs were littermates of four 60 kg crossbred animals (DL x DY). They had free access to 20-30 cm high clover grass and water supply was placed on the deep litter area as a drinking manger with nipple and bowl (FROSTLINE®). The feed consisted of pellets for slaughter pigs made from organic ingredients to ensure the organic standard compliance.

There was a manger per pig during the feeding. The plan was to feed the pigs twice a day. The order of the groups for feeding was random.

The pigs defecating in the paddock were mapped by way of the manure collected and weighted to estimate the amount of manure distributed in the paddock

The case study period lasted 9 feeding days in late November 2006 and early December 2006.

Feeding procedure

The FeederAnt was driven from the barn to the field and the paddock navigated by use of a joystick. The feeder was filled with pellets for one group just before it went into the paddock. It was navigated through the electric gate and placed in a new position in the paddock. When the FeederAnt reached the intended position, the pigs began eating immediately. The feeding lasted 20 minutes or until all four pigs had left the feeder. Then the FeederAnt was moved to the next paddock. Operating the FeederAnt can be seen at http://video.google.com/videosearch?q=feederant

Results

The weather conditions during the days of the case study were very windy, cloudy and moist or rainy. The pigs came out from the tent upon hearing the FeederAnt approaching and went back into the tent again not later than 15 minutes after the FeederAnt had relocated to the next paddock. Because of that, it was impossible for one person to observe the urinating behaviour of the pigs and at the same time manage the feeding of the pigs in the next paddock. Due to limited time resources, the pigs were only fed once a day instead of two times per day.

Operation of the FeederAnt

It was difficult to navigate the feeder because that the four traction wheels were placed in the middle under the FeederAnt and the four auxiliary wheels were placed in the corners of the feeder. When one or two of the auxiliary wheels ran into a wheel track or a hole, the traction wheel was forced in that direction which meant that it became difficult to navigate and move the robot in the right direction, at least until the auxiliary wheel was out of the track again. The robot successfully moved through the electric gates except for the frame of the FeederAnt which could occasionally grasp the gate wires. This problem was solved by displace the lowest electric gate wires. The robot experienced difficulty in moving through a very rooted area and the last two days it could not traverse the part of the paddock closed to the tent.

The Case Study

At the first day of using the FeederAnt, it took the three groups of pigs 5 to 20 minutes to find the feed in the manger and the fourth group was not interested but ate clover grass in stead of feed pellet. At the second day, all pigs with the exception of one had learned to eat from the FeederAnt. This one pig was moved to another paddock between day 2 and 3. At the third day, this pig ate from the FeederAnt together with the mates in the new group. There were very few pushes and bites, less than one per pig per feeding. (See table 1) However, the pigs did not stay in the same place duing the whole feeding time but moved from one manger to the other. This could be seen as a result of too narrow manger space.

Whenever the pigs heard the feeder, they entered the paddock and followed the feeder movements. They never tried to cross the electric gate but if the robot moved slowly, the eating occasionally commenced before it reached its position.

Table 1. Pushes and bites among slaughter pigs during feeding.

Groups	**No 1**	**No 2**	**No 3**	**No 4**
No of pigs per group	5	4	3	4
No of feedings per group	8	8	8	8
No of feeding minutes per group	144	134	139	144
No of pushes per group	29	24	0	11
No of bites per group	7	2	0	2
No of fights per group (minutes per fight)	0	0	1 (9)	1 (3)

Fighting among the pigs was defined as pushes and bites directed against one or more littermates at a rate in which it was not possible to observe each attack. There were pauses in the fights, and the fights ended when one of the pigs realised that feed also was available on the other side of the feeder. Pushes and bites were single occurrences carried out by one pig against another. Overall aggressions were not completely eliminated but the occurrences were rare.

When the FeederAnt had been in the paddock for maximum 20 minutes or when the last pig had left the manger, the robot was moved out of the paddock and into the next one. The pigs only stayed out and rooted or grazed in 10 to 15 minutes and then went back to the nest in the tent because of hard weather. One day with very heavy rain, the pigs in the one group ate for 10 minutes and then ran to the tent again with out waiting for the robot to be moved.

The major amount of manure was placed in distances from 10 m to 20 m from the tent, which is in accordance with Benfalk *et al.* (2005). The distribution did not seem even from one paddock to another.

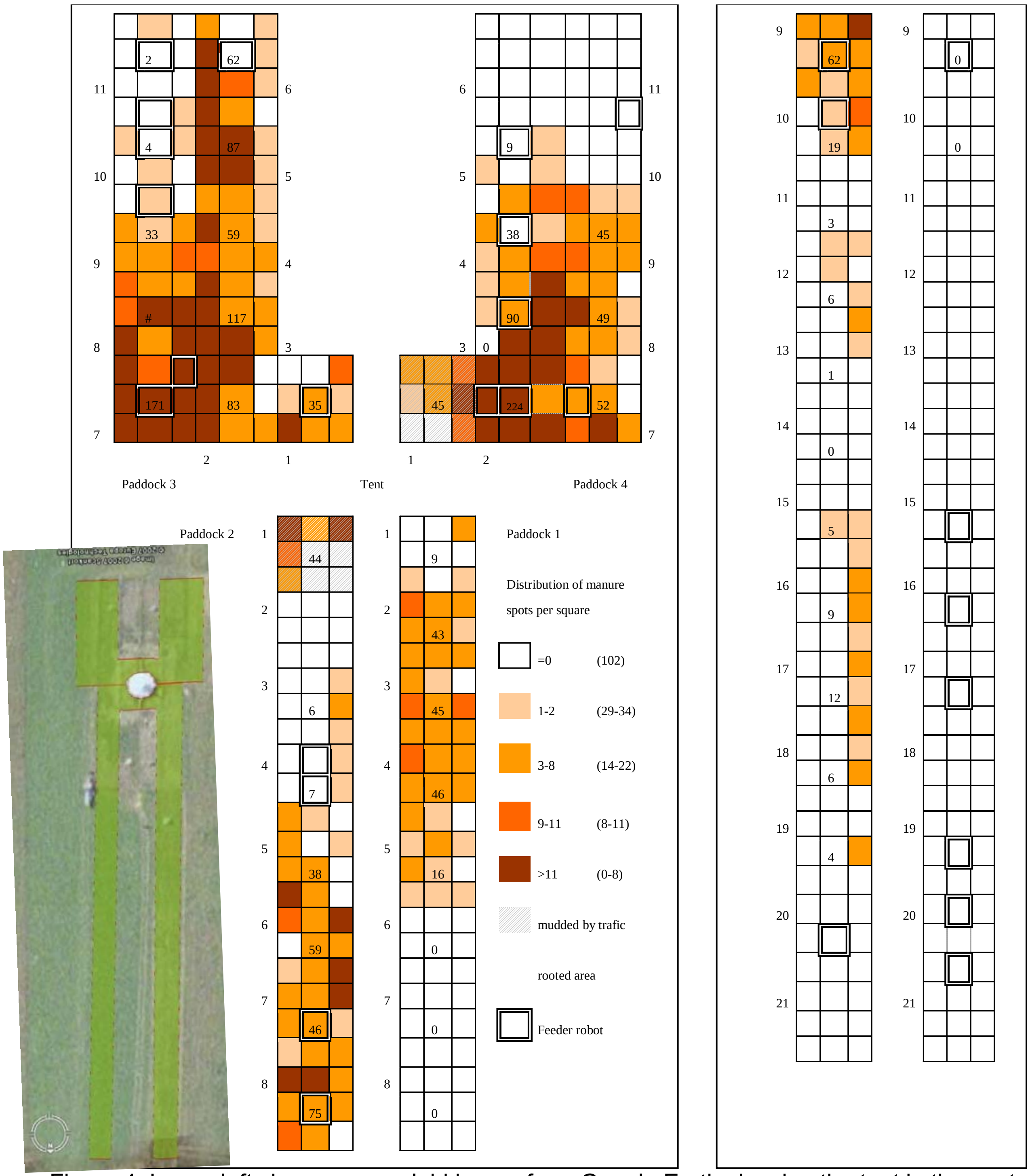

Figure 4. Lower left shows an overlaid image from Google Earth showing the tent in the center with the 4 paddocks illustrated with the yellow green polygons. Lay out of grass paddock in connection with pig tent where the lower end of paddocks 1 and 2 has been shifted up to the right. The colored squares show the distribution of manure when the pigs had defecated in the paddocks. The paddocks are visually subdivided in squares at 6.6 m x 6.6 m and one colored plot is 2.2m x 2.2 m.

In one paddock, the pigs had rooted the major part of the ground and it was not possible to distinguish between soil and manure. However, building on other studies, pigs defecate on their way from the nest to the feed location in the morning. When grazing constitutes a great part the activities of the pigs, they will defecate and urinate while they are grazing. If they need to mark their territory, they will defecate along the border or fences. Having this in mind, positioning the feeder in a new place at every feeding will result in a more even distribution of the manure and urine if the paddocks are not too narrow and long. When the paddock is narrow, the pigs have to follow the same path every day from the nest to the feeder and they may have a need to mark their path along the fence.

Discussion

The traction wheels should be placed in the corner of the robot to ensure better navigational control. Furthermore, when the four traction wheels are placed in the corners of the feeder frame, the unit will be more steady-going and manoeuvrable when it must pass wheel tracks or a hole.

The pigs were generally not alienated in terms of behaviour towards the robot. Hence, this preliminary study seems to indicate that the pigs accept the autonomous feeder rather quickly into their environment and are able to familiarize themselves with the functionalities, like finding the feed within the feeder. In this way, the concept of using an autonomous robot for nursing pigs seems plausible.

The aggression level among the pigs was very low because the configuration allowed the all the animals to have easy access to the feeder and there were enough room for all animals at the manger. In terms of sufficient time for eating, there should be at least two feedings per group per day.. One feeding per day was not enough to have the pigs eat their daily ration, even if they had free access to roughage and was thought to have a sufficient stomach volume.

The pigs had difficulty in eating the pellets in the corners and in the front of the manger because of the triangle design of the manger walls. This indicates that the mangers should be designed according to the shape of the head of the pigs. When the pigs have easier access to the feed it is supposed that they will, to a lesser extent, drift from manger to manger but stay and eat their ration of feed.

One wire in the electric gate placed 30 cm above the ground was sufficient to keep the pigs within the confinement. The wire was visible for the pigs and appeared deterrent enough for the pigs not to follow the robot outside the fencing.

New technologies will help rationalizing the animal management by making it easy to use wireless control and develop autonomic self-propelled nursing robots

Conclusion

A concept involving a mobile feeding system for outdoor piglets has been documented in this study. A remotely controlled feeding unit (The FeederAnt) was able to feed several pens with piglets. This way of feeding helps distributing the manure from the animals more evenly within the grass paddock preventing point leaching of nutrients. The most even distribution of the manure can be achieved using paddocks not too narrow and long and when positioning the feeder in a new location at every feeding. The FeederAnt replaces many stationary feeding tables and reduce the amount of daily manual feeding routines.

However, some technical functions of the FeederAnt have to be improved. The unit must be more steady-going and manoeuvrable. Also, the unit must be developed into an autonomic feeding system based on a global position system. The control computer must be provided with route planning program in order to derive the driving routes and feeding positions.

Acknowledgements

This research was supported by The Directorate for Food, Fisheries and Agri Business, Denmark (DFFE). We are grateful to Sales manager Jan Formánek, Dvořák Machine Devision, Czech Republic, for technical assistance with concern to the Spider ILD01 slope mower.

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