"Ready for Autonomy (R4A)": concept and application for autonomous feeding

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Abstract: This paper presents the development of the "Ready for Autonomy (R4A)" application for evaluating the feasibility of integrating an autonomous feeding machine Strautmann Verti-Q into farmyards and evaluating the machine's performance. The proposed application consists of three main R4A checklists for telling whether the farmyard, the machine, and the farmer are ready for autonomy or not. The farmyard is the first part to be checked with the R4A application with the Verti-Q system requirements. The R4A result will be instantly generated from the application based on the Boolean function. The second part is the machine operation record which tells the overall performance of the Verti-Q machine as the R4A distribution results, e.g., excellent, good, and failure. The final part is the farmer operation training in manual and autonomous modes, in which farmers have to go through every topic to be ready to use the machine. From the experimental results, seven farmyards were observed with the R4A application. Therefore, the four farmyards are ready for autonomy with different R4A levels. The minimum working condition of the Verti-Q machine has been tested on the lowest R4A level farmyard. The distribution results from the prototype machine with 218 autonomous feeding jobs, achieving 42% in excellent distribution, 38% in good condition, and 21% in failure caused by various reasons, e.g., hardware, software, and user error, respectively. These results show the possibility of using the improved version of the autonomous feeding machine in the farmyard for sustainable farming in the future.

Keywords: feeding machine, autonomous system, feed distribution, farm-scale experiment, self-driving, mobile application

1 Introduction

A development study for the first autonomous feeding machine covering the complete feeding process on the farm ("Verti-Q") was presented at Agritechnica 2017 by Strautmann. This machine automatically picks up feed components in various silos, navigating across the yard to the barn, mixing the feedstuffs and feeding it to the cows [Ru21]. The advantage of time, feed management (Verti-Q Fütterungssystem), and the flexibility of the autonomous and person-bound operation make the system attractive to

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the market. However, due to the operation safety system with high-performance safety sensors [Me18; Me21], the system commissioning process and the specific working conditions are still needed. In the research project "Experimentierfeld Agro-Nordwest", the concept of this work focuses on integrating the Verti-Q machine into the minimum requirement farmyard and testing the prototype of the Verti-Q machine in the real farm test for the autonomous feeding mode. Various parameters from the Verti-Q system requirements, such as the driving path parameters, landmarks, and safety issues, can be confusing to process at the R4A level.

This work presents a mobile application called "R4A application", which takes three important keys to define if a farmyard, the machine, and the farmer are ready for autonomy or not. As a consequence, R4A can be a valuable tool for speeding up the transfer of sustainable technologies into practice. Based on the Google spreadsheet database, this application was developed on the Glide App platform, which is available for Android and iOS systems.

The advantage of the generated log file from the R4A mobile application is that it helps to analyze the R4A level and can easily track the experiment process. The R4A level results show the possibility of improving the prototype of the Verti-Q machine in the farmyard for sustainable farming in the future.

2 Material and methods

This section describes the R4A application implementation, and Figure 1 shows the design concept. The application consists of three main parts for R4A levels, the farmyard requirement, the machine operation record, and farmer operation training, and the additional information part, e.g., the address of the farmyard, the number of cows, the mixing ratio as well as the manual feeding process.

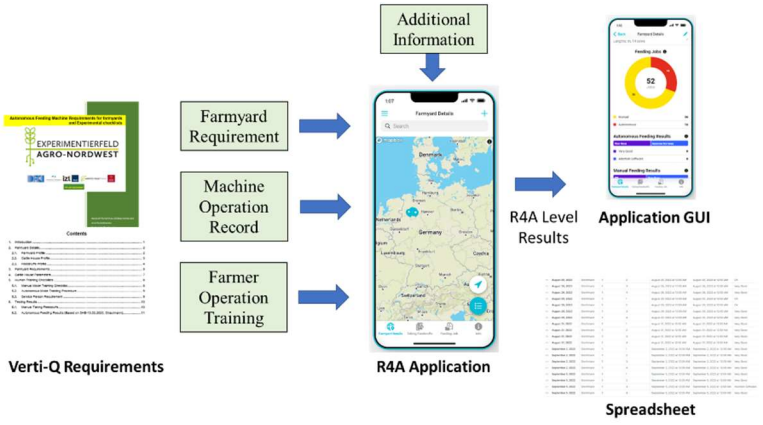

Fig. 1: R4A application structure

2.1 Ready for Autonomy of the farmyard

This experiment developed the R4A levels for farmyards based on the Boolean function. From the Verti-Q system requirements, as shown in Table 1, all required values have to be checked as "Yes", and the R4A level for the farmyard can be calculated from Eq. 1, and the R4A result will be instantly generated from the application. If not ready for autonomy, the farmer has to improve the farmyard condition if possible. If the farmyard is ready for autonomy with the R4A level, it means that it is technically ready to use the Verti-Q machine.

$$R4A_{farmyard} = \boldsymbol{tw_v} + \boldsymbol{ch_v}, \text{ where } tw_v \geq 3.5 \text{ and } ch_v \geq 3.5 \quad (1).$$

Symbol	Track Parameters	Required	Scoring
$\boldsymbol{p_a}$	Acceptable gravel and the pavement surface	Yes	Yes = 1 No = 0
$\boldsymbol{g_a}$	The gradient between indoor and outdoor	<5 °	
$\boldsymbol{i_a}$	Incline path	<8 °	
$\boldsymbol{s_a}$	Step between indoor and outdoor	<30 mm	
$\boldsymbol{lm_a}$	Landmark installation area available	Yes	
$\boldsymbol{sf_a}$	Straight feeding tables	Yes	
$\boldsymbol{fm_a}$	Farmer confirmation that no persons in the autonomous area	Yes	
$\boldsymbol{tw_v}$	Track width everywhere (Minimum requirement)	>3.5 m	$\boldsymbol{tw_v}$
$\boldsymbol{ch_v}$	Clearance height (includes cattle house gate)	>3.5 m	$\boldsymbol{ch_v}$

Tab. 1: Verti-Q system requirements

To test the Verti-Q machine on the lowest limitation, this experiment will select the farmyard from the lowest score of $R4A_{farmyard}$. Figure 2 shows the commissioning process. Due to the Verti-Q machine navigation system using ultrasonic sensors to navigate the machine while feeding autonomously, ultrasonic landmark installation and landmark calibration with the Verti-Q machine are needed.

Landmark installation | Installed landmark | Landmark Calibration

Fig. 2: Verti-Q system commissioning process

2.2 Ready for Autonomy of the machine

This part is the machine operation record. The feeding job details from Verti-Q, e.g., date-time, distribution results, photographs, and error codes, will be recorded and reported on the R4A application. The R4A level for the machine will be categorized into three levels by the distribution level, e.g., excellent means the feed distribution is uniform, not lacking or exceeding, good means the feed distribution is uniform was slightly uneven but can also be distributed evenly for all cows, and failure means the autonomous mode cannot work or it does not finish the feeding job because of the system interruption. In case of a machine failure, these records will be investigated by the authorized technician.

Fig. 3: R4A machine operation record

2.3 Ready for Autonomy of the farmer

This part is the farmer operation training in manual and autonomous modes. In the manual mode, farmers must learn to use the Verti-Q machine, e.g., driving, taking feedstuffs, mixing, weight monitoring, protector control, etc. The user instruction for the autonomous user interface called “Verti-Q Fütterungssystem”, e.g., feeding table management and feed schedule, will be described in this part. In case of a system interruption, system failure, and emergency issue, farmers must be able to solve these problems, which can use the emergency stop system and switch back to operating in manual mode. However, the people operating the Verti-Q machine are not only the farmer. The checklist for authorized technicians is also included in this section, e.g., system commissioning, machine calibration, and machine maintenance processes. Moreover, based on the feedback of the farmers the R4A human-machine-interface can be improved.

3 Results and discussion

For the farmyard, Table 2 shows the results of the R4A level for eight farmyards, the prototype farmyard (Farmyard A), and the experimental farm (Farmyard B-H) from the site survey. From Farmyard B-H, three of them, Farmyard B, E, and F, are not ready for autonomy due to the old-style cattle house, big steepness in front of the gate, and too small entrance gate. On the other hand, four of them, Farmyard C,D,G, and H are ready for autonomy. To investigate the minimum requirement, the lowest R4A level, "Farmyard C", was chosen in this experiment with the smallest cattle house gate. For the Verti-Q machine, the distribution records are shown in Table 3. This experiment is divided into three phases, P1 for testing the Verti-Q prototype, P2 for testing the improved version of Verti-Q, and P3 for testing the Verti-Q on the new commissioning area (Farmyard C). The percent failure of P1-P3 achieves 53%, 15%, and 12%, respectively.

Track Parameters	**Farmyard**							
	A	**B**	**C**	**D**	**E**	**F**	**G**	**H**
$\boldsymbol{p_a}$**:** Acceptable gravel and the pavement surface (Yes)	Y	Y	Y	Y	Y	Y	Y	Y
$\boldsymbol{g_a}$**:** The gradient between indoor and outdoor (<5 °)	Y	Y	Y	Y	Y	Y	Y	Y
$\boldsymbol{i_a}$: Incline path (<8 °)	Y	Y	Y	Y	N	Y	Y	Y
$\boldsymbol{s_a}$**:** Step between indoor and outdoor (<30 mm)	Y	Y	Y	Y	N	Y	Y	Y
$\boldsymbol{lm_a}$**:** Landmark installation area available (Yes)	Y	N	Y	Y	Y	Y	Y	Y
$\boldsymbol{sf_a}$**: Straight feeding tables** (Yes)	Y	Y	Y	Y	Y	Y	Y	Y
$\boldsymbol{fm_a}$**:** Farmer confirmation that no persons in the autonomous area (Yes)	Y	N	Y	Y	Y	Y	Y	Y
$\boldsymbol{tw_v}$**:** Track width everywhere (>3.5 m)	Y	N	Y	Y	Y	Y	Y	Y
$\boldsymbol{ch_v}$**:** Clearance height (>3.5 m)	Y	N	Y	Y	Y	N	Y	Y
$\boldsymbol{R4A_{farmyard}}$	**9**	**-**	**7.1**	**7.8**	**-**	**-**	**9.5**	**8.4**

Tab. 2: R4A level for farmyard results

Phase/Farmyard	**P1/A**		**P2/A**		**P3/C**		**Total**	
	Jobs	**%**	**Jobs**	**%**	**Jobs**	**%**	**Jobs**	**%**
Excellent	7	18%	33	32%	51	67%	91	42%
Good	12	30%	54	53%	16	21%	82	38%
Failure	21	53%	15	15%	9	12%	45	21%
Total	**40**	**100%**	**102**	**100%**	**76**	**100%**	**218**	**100%**

Tab. 3: R4A level for Verti-Q machine results

The last checklist is the R4A level for the user/farmer. This work has classified users into three levels consisting of L1: farmers who operate the feeding machine, L2: authorized technicians who operate the commissioning process and fix some problems, and L3: Strautmann Product R&D: who can improve the performance of the machine. Table 4 shows the percentage of autonomous failure solved by the user at each level.

Problem solved by user level	Phase P1/A	Phase P2/A	Phase P3/C
L1: Farmers	13.0%	20.0%	33.3%
L2: Authorized Technician	34.0%	46.7%	56.6%
L3: Strautmann Product R&D	53.0%	33.3%	11.1%

Tab. 4: R4A machine failure solved by each user level

4 Conclusions

The "Ready for Autonomy (R4A)" application was developed for evaluating the R4A levels for the farmyard, the machine, and the farmer. In the experiment, the autonomous failure was reduced from 53% to 12% from three phases, with a 21% failure average. In the failure case, the farmers and authorized technicians can solve the problem by themselves, increasing from 13.0% to 33.3% and 34.0% to 56.6%, respectively. While the problem solved by Strautmann R&D decreased from 53% to 11.1%. These results show the possibility of using the improved version of the autonomous feeding machine in the farmyard for sustainable farming in the future.

Acknowledgement: The project "Agro-Nordwest" is supported by funds from the Federal Ministry of Food and Agriculture (BMEL) based on a decision of the Parliament of the Federal Republic of Germany via the Federal Office for Agriculture and Food (BLE) under the innovation support program. We also thank Heinz Georg Plogmann-Große Börding and Stefanie Grothmann, the farmer who gave us the experiment area.

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