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Automatic Data Acquisition on Round Balers

by

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Summary:

A round baler was equipped with a PC-based data acquisition system, GPS receiver and different sensors for automatic gathering of machinery parameters, working time and local yields. Algorithms were developed for an automatic analysis of the data acquired.

Keywords:

Data acquisition, data analysis, round baler, GPS, machinery parameters measurement, working time measurement, local yield measurement

Automatic Data Acquisition on Round Balers

K. Wild, H. Auernhammer, J. Rottmeier[1]

Introduction

Agriculture in the past was mainly assessed according to economic aspects. Today this is changing more and more towards an improvement of the whole farm system management and towards a consideration of environmental protection. All of this is a new challenge which calls for changing the patterns of agriculture. Therefore more high quality data and better information are necessary, all of which must be handled and processed. Very often data gathered manually are inadequate to meet requirements. They may have many gaps, are very often unprecise and may be saved in a format which can not be accessed by computers.

Hence automatic data acquisition will be of increasing importance in the future: First for cost reduction, second for improved labor management and last, but not least, for the needed inputs for site specific crop management.

Machinery costs constitute a high proportion of total production costs. They can only be lowered if sufficient information is available about machinery use, so that the cost incuring factors can be detailed. The machine operator is not capable of gathering the needed information. High quantity and quality data acquisition is only possible with an automatic system.

The same considerations apply to human labor as well. Labor costs also have a major impact on the economic result of a farm enterprise. Especially for comparative timing of individual machines and workers, a lot of data are necesary and very often a diagrammatic approach is indispensable.

Finally, there is the natural environment, which is not constant but changing by geographical location and time. Site specific crop management requires a high geographical resolution as well as a high resolution for quantities. This leads to large data amounts, which are out of range for manual handling.

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Objectives

Since 1992 experiments have been carried out with a round baler. The focus of this project has been on two goals.

The first goal was to establish an automatic data acquisition system. For measuring different parameters, appropriate sensors had to be selected and tested. Also, a suitable recording system had to be set up.

The second goal was to develop algorithms for analyzing the data gathered. The algorithms were for incorporation in computer programs, so the data could be analyzed automatically.

There are many important sources of information for farm and crop management, which occur during a harvesting operation with a round baler. For this project some significant parameters were chosen to be measured in three groups (Tab. 1).

Table 1: Important farm data for harvesting operations with a round baler.

Machinery parameter	Working time	Harvested material
Power requirements Operating time Down time Average working speed Average effective capacity	Total time Effective time Preparation and adjustment time Travel time Down time Idle time Operator's personal time	Total yield Local yield Dry matter content

Besides aiding in cutting down costs, machinery parameters are also necessary for improving performance and scheduling operations. For improving the time efficiency of field operations much more information is required than just the total time. Data, such as preparation, adjustment, travel, down, idle or transport time are needed as base for a better time management.

Yield was and always will be an important factor. But for site specific crop management not the total yield, but the local yield is the significant element. For deriving the local nutrient withdrawals by the harvested biomass, the dry matter content - especially of crops with highly varying dry matter contents - has to be determined on-the-go.

Finally, all parameters should be measured together with the position of the vehicle. With the satellite based NAVSTAR - Global Positioning System (GPS), a tool is now available, which can be used by everybody for sensing location.

GPS not only provides the current location it also gives many other pieces of information, like travel speed or time. Therefore GPS can be employed as a clock for working time measurements (Fig. 1).

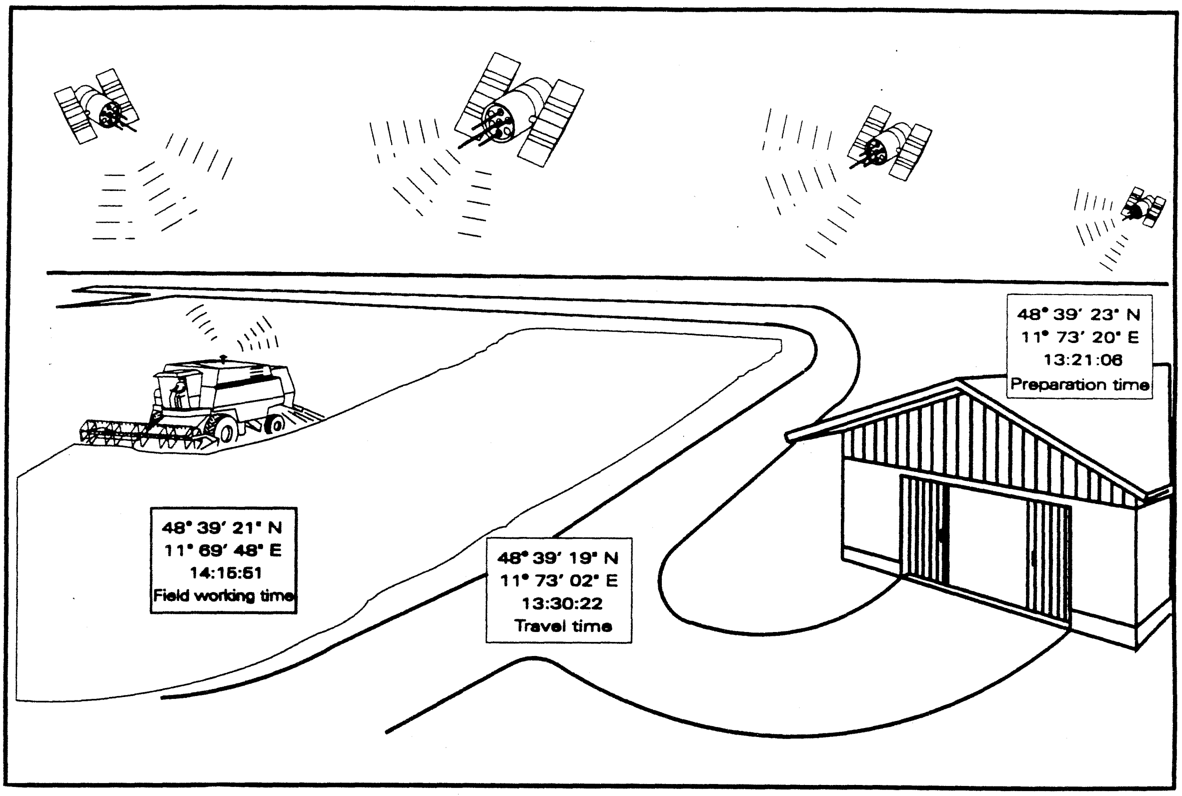

Figure 1: GPS as a basis for an automated system for operating time measurements.

By recording the starting and ending time of operations, the duration time can be determined. By knowing duration and location, basic information is gained about time usage. For example, if a vehicle is located in or near the barn/workshop, then it can be assumed that preparation is in progress, or if the position of the vehicle is on the road, then time is being used for traveling.

So, GPS can be used as a basis for an automated system for time measurement. But still large time blocks, e.g. field working time, with different elements can remain. A further division is necessary. For this task additional sensors are helpful.

Materials and Methods

A tractor and a round baler were fitted out with sensors, not just for time measurements, but also for data acquisition on machinery use and yield (Fig. 2).

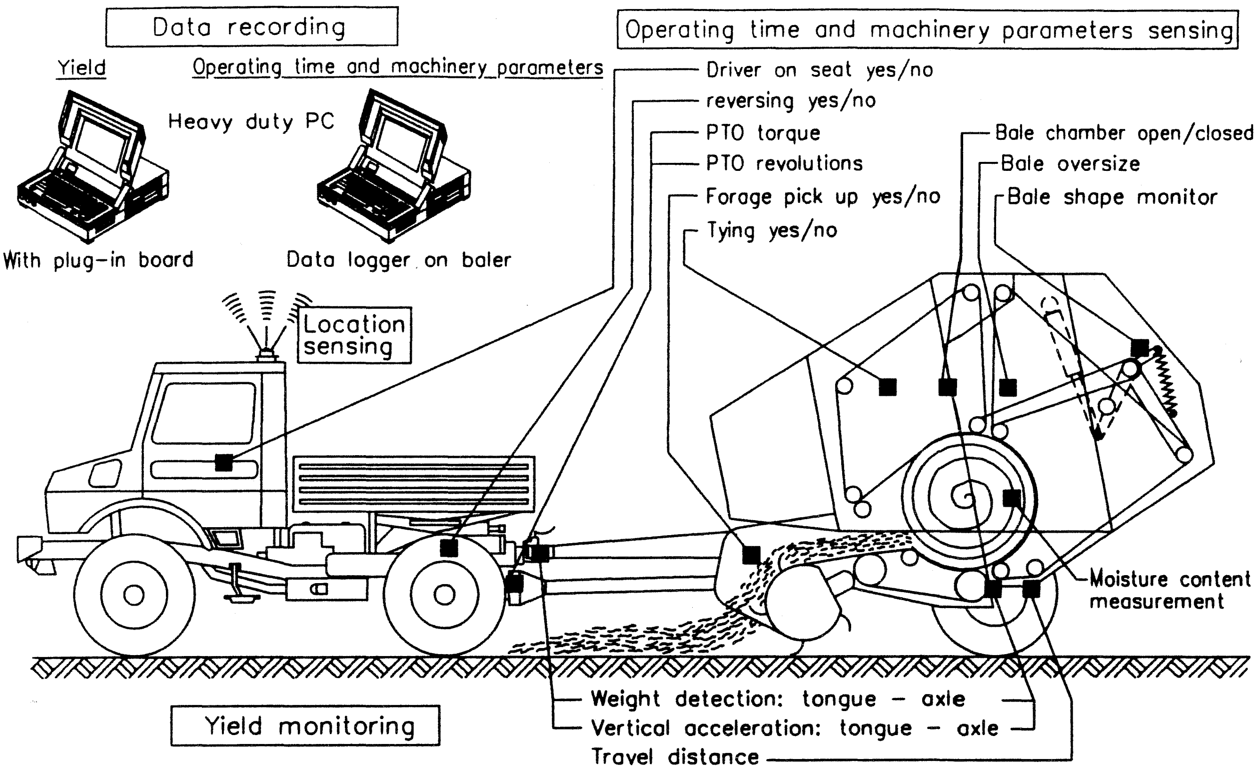

Figure 2: Sensors and acquisition system on the tractor and round baler.

The data acquisition system was not only based on newly installed measuring devices, but also on sensors, which were standard components of the equipment.

For the tests a "UNIMOG U 140" from MERCEDES BENZ or a "FARMER 306LSA" tractor from FENDT and a round baler model "550" from JOHN DEERE were used.

Location sensing was carried out in differential mode (DGPS). The primary receiver on the UNIMOG was a 8-channel parallel receiver, model "GN-72" from FURUNO. The base station was installed at a farm, where most of the experiments were conducted. The base station used was a "GPSCard OEM 2100" from NOVATEL which provided 10 channels. The position correction information, based on RTCM SC104, was transferred via modem and radio to the rover for real time position correction. Also, receivers from ASHTECH (MXII) were employed. Then the differential correction was carried out in post processing. The update rate was either once per second or once per 3 seconds.

Machinery Parameters

For determining the baler's power requirements, PTO torque and revolutions were measured. The revolution meter also indicated when the baler was running. Distances traveled were measured by counting revolutions of the baler wheel (reed sensor) and with GPS. The number of bales made was detected by counting the tying events. This information was read from the baler monitor. Data about bale shape and size, also provided by the monitor, were gathered as well.

Working Time

A one-way photo electric guard, the beam of which ran horizontally across the pick up, detected when forage was being picked up. The status of the bale chamber (open or closed) and whether tying was in progress or not were acquired from the baler monitor. Reversing of the vehicle was detected by reading the reversing light. A switch in the driver's seat detected when the seat was occupied.

Values on machinery parameters and operation time were measured with an "IMP" - datalogger from SCHLUMBERGER with a sampling rate of 1 Hz and saved on a heavy duty PC from KONTRON ("IPLite 486").

Harvested Material

Yield monitoring was carried out by weighing the baler with the bale. For this purpose strain gages were applied at the tongue and at both ends of the axle of the round baler. For assisting the weight detection, acceleration sensors for measuring vertical accelerations were placed next to the strain gages.

All yield and acceleration data were acquired with an A/D converter board ("RTI 834" from ANALOG DEVICES) with a resolution of 12 bits. The A/D converter board was plugged into a second IPLite - PC. The data measured were saved on the hard drive of the PC. The weights and the accelerations were measured on-the-go with a sampling rate of 200 Hz. In addition, the weight was also detected in stationary mode (baler stopped, not running) after tying.

Results and Discussion

For analyzing the machinery data and working times special algorithms had to be developed. These were implemented in a computer program, written in the "C" language. The yield data were processed with standard analysis software.

Machinery Data

With the measured PTO torques and revolutions the power requirement for the round baler could be determined (Fig. 3).

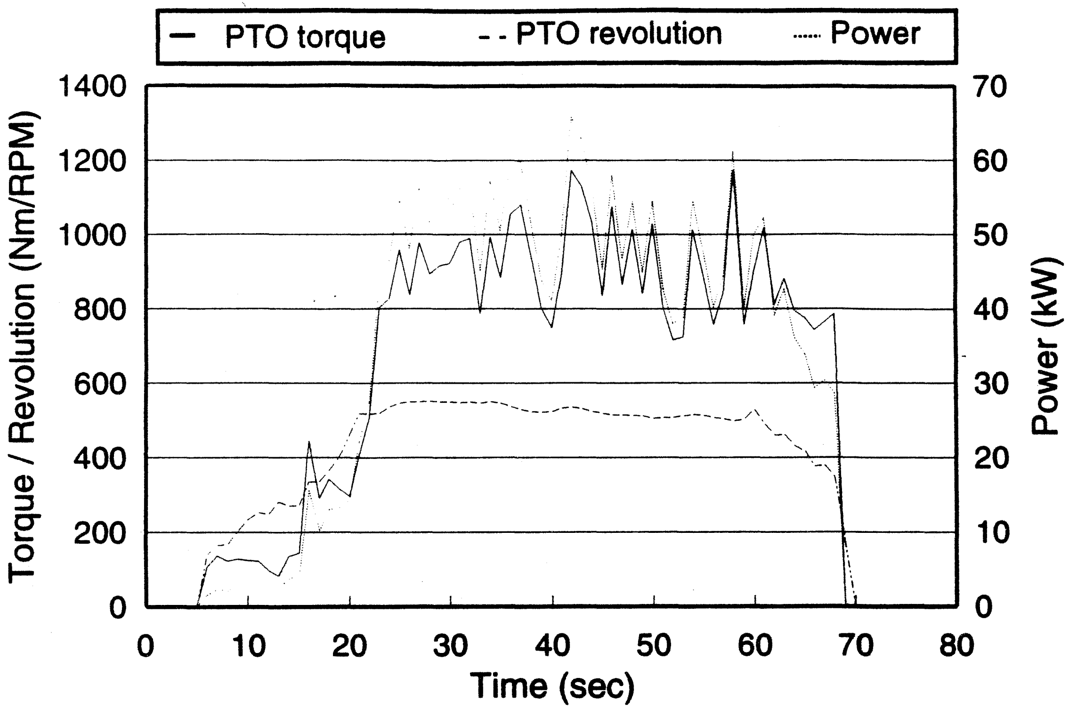

Figure 3: Power requirement of the round baler.

The plot shows a typical course for power usage of a round baler with a variable size baling chamber. Because of the low frequency update rate of 1 Hz the torque graph, and therefore the power graph as well, show a very angular pattern.

Also many other parameters could be determined from the data files (Tab. 2).

Working Time

The first step of analysis was to divide up a data file into three parts according to the position of the UNIMOG and attached round baler: farmstead, road and field. This was carried out by using the position of the vehicle, determined with GPS. Next the partition with the field data was investigated in order to find the strings, which show the beginning and the end of the making process for each bale. Then each of these subsets was analyzed. The individual working elements

Table 2: Machinery parameters determined for round baling (Angerwiese, 3 ha, 21. Sept. 1994).

Field capacity	2.4 ha/hr
Material capacity	20.2 bales/hr
Travel distance for forage pick up	2500 m
Average working speed	6.5 km/hr
Operating time (PTO turned on)	42.7 min

were detected with combinations of sensor readings like those shown in Table 3.

Table 3: Combinations of sensor readings for determining working elements.

Picking up	**Turning**
· Bale chamber closed · Sensor at pick up indicates picking up · PTO revolution > 5 RPM · Travel speed > 0.1 km/h · Tying sensor indicates no tying · Position in field by GPS	· Sensor at pick up indicates no picking up · Travel speed > 0.1 km/h · Tying sensor indicates no tying · Position in field by GPS
Tying	**Interruption**
· No picking up · No turning · Tying sensor indicates tying · Position in field by GPS	· No picking up · No turning · No tying · Position in field by GPS

To rely on only a single sensor for detecting an element automatically leads very often to erroneous results. One reason for this are modifications in the bale making procedure. Every bale can be produced in a slightly different way, due to operators personal preferences or to machinery breakdowns.

As an example, the following material shows the results for baling in a meadow ("Angerwiese") in September 1993. Twenty-five bales of grass for silage production were made on this 3 ha plot.

For checking the accuracy of the data acquisition system and the analysis methods, times were also measured with a stopwatch.

After finding the start and the end strings for each bale, the times for forage pick-up per bale were determined and compared with the stopwatch measurements (Fig. 4).

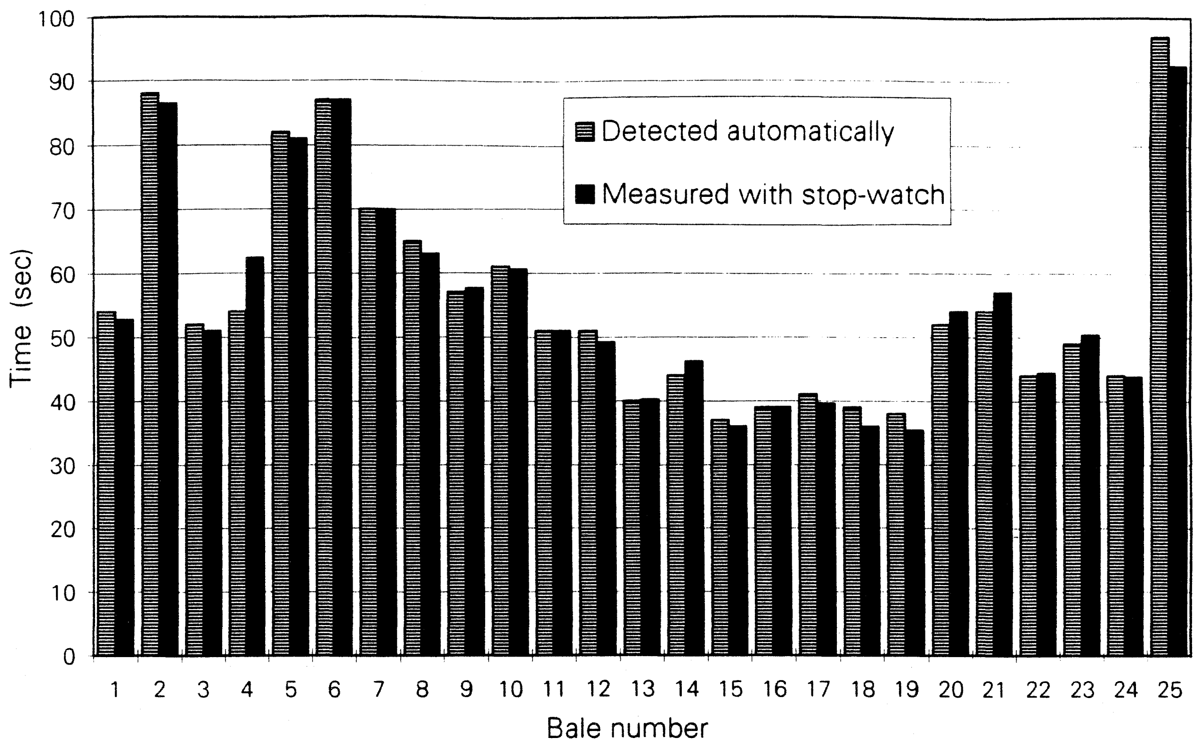

Figure 4: Pick up time per bale (Angerwiese, 3 ha, 21. Sept. 1993).

The deviations ranged from -8 sec up to 5 sec. With an average deviation per bale of 0.1 sec and a standard deviation of 2.4 sec, the errors were small.

In Figure 5 the times for turning per bale are presented. For most of the bales the turning times detected automatically show no or only small deviations. But for bales like number 4 or 22 the errors are 16 and 17 sec. Because of the low absolute time values for turning, the relative errors for these two bales are very high: 80 and 63 %.

At present the analysis algorithm can not detect turnings which follow immediately after tying. Erroneously the analysis program determines these turnings as tying. For this reason, the total turning time is underestimated by 12 %, whereas the total time for tying is overestimated by 2.5 % (Tab. 4).

Nevertheless, as is visible in the last column of the table, the deviations as a proportion of the total time for turning and tying are still smaller than 1.5 %. The percentage for tying was found to be exceptionally high (58 %). That is because this part also includes times for additional measurements: Immediately after tying and right before expelling a bale, the machine was stopped for stationary weight measurements.

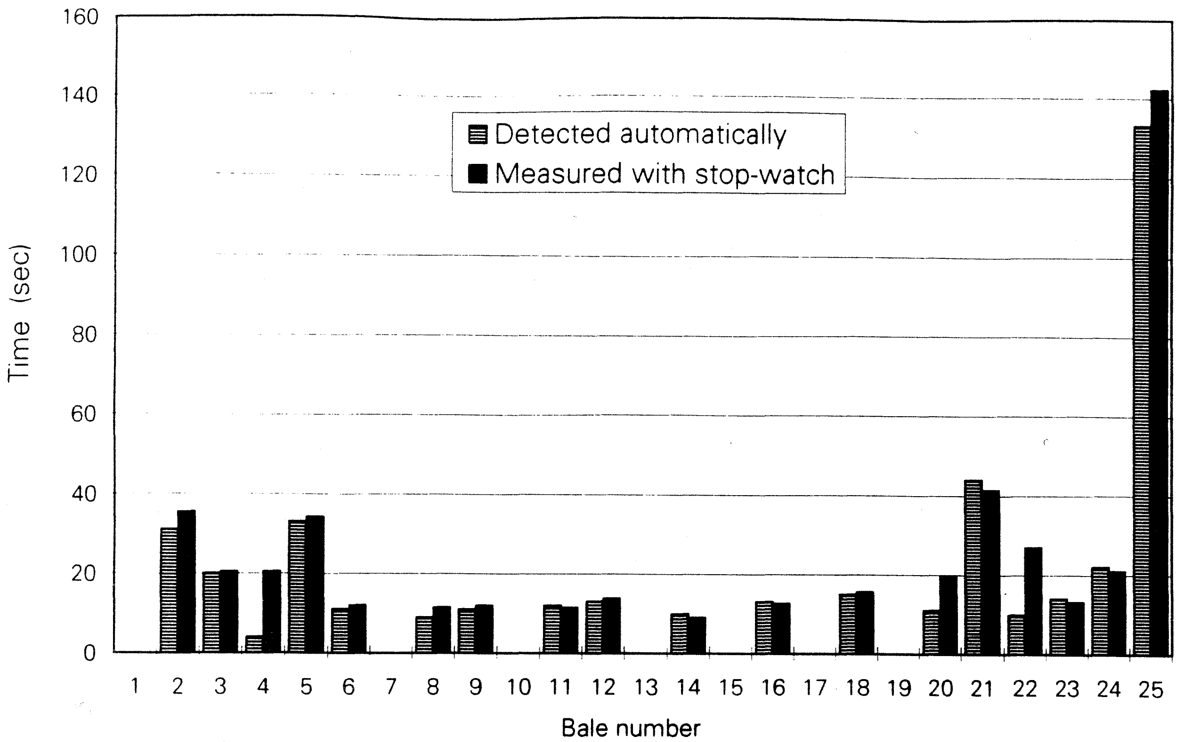

Figure 5: Turning time per bale (Angerwiese, 3 ha, 21. Sept. 1993).

Table 4: Time usage during round baling.

	Measured with stop-watch (min)	Relative share (%)	Detected automatically (min)	Difference (%)	Difference as share of total time (%)
Total time (without travel and preparation)	74.35	100.00	74.37	0.03	0.03
Time for picking up forage	23.26	31.28	23.17	-0.39	-0.12
Turning time	7.88	10.60	6.93	-12.06	-1.28
Tying time (incl. time for weighing)	43.21	58.12	44.27	2.45	1.42
Down time	-	-	-	-	-

In the following step the vehicle positions, sensed with GPS were used for plotting the trace of the tractor - round baler combination (Fig. 6).

The shape of the field was irregular. In the south west corner the farm yard is located. Also the field boundaries did not make straight lines, due to the natural environment. All 18 swaths can be seen easily (Fig. 6), also the cross swath in the southern and northern headland can be seen. In addition, there was a short swath in the headland just north of the farm yard. The tractor started baling in the south east corner, went around the plot (clockwise) and then baled one swath after another from east to west.

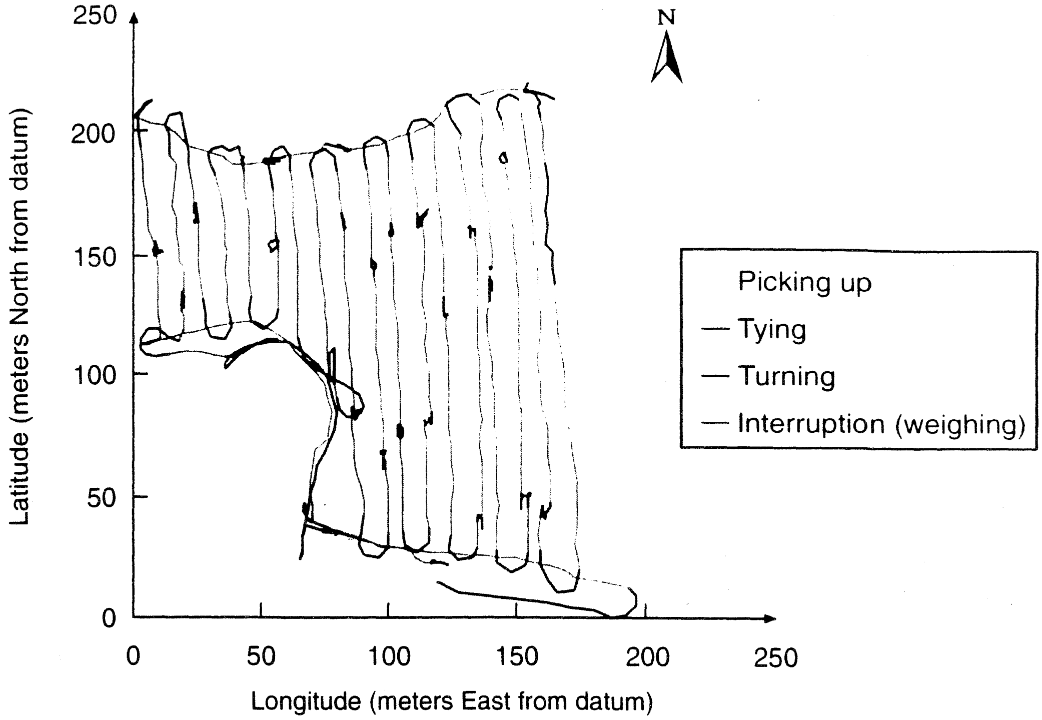

Figure 6: Trace map of the pattern of operation (Angerwiese, 3 ha, 21. Sept. 1994).

By investigating the trace map, it can be concluded, that the positioning accuracy was within a few meters. The turns appear angular due the fact, that the positioning update rate was only once per 3 seconds.

Figure 6 shows not only the trace of the harvesting machinery, it also shows the pattern of operation (see Appendix for color output of Fig. 6). This pattern was gained by associating each position with the corresponding operation. Picking up and turning are clearly visible. Accumulation of points means that the equipment was not moving. The interruptions were caused by the procedure required for carrying out the experiment. As already mentioned, tying a bale was followed by stationary weighing.

Yield Sensing

The focus of these tests with the round baler were on local yield detection. As already shown in earlier publications, the weight of bales could be measured with errors less than 2 %. Prerequisite for this high accuracy is that the baler is not running and stopped while the weight is measured. But local yield detection has to be carried out on-the-go. This means that the weight signals are interfered with vibrations, caused by rotating machinery parts and by rough ground surfaces (Fig. 7 and 8).

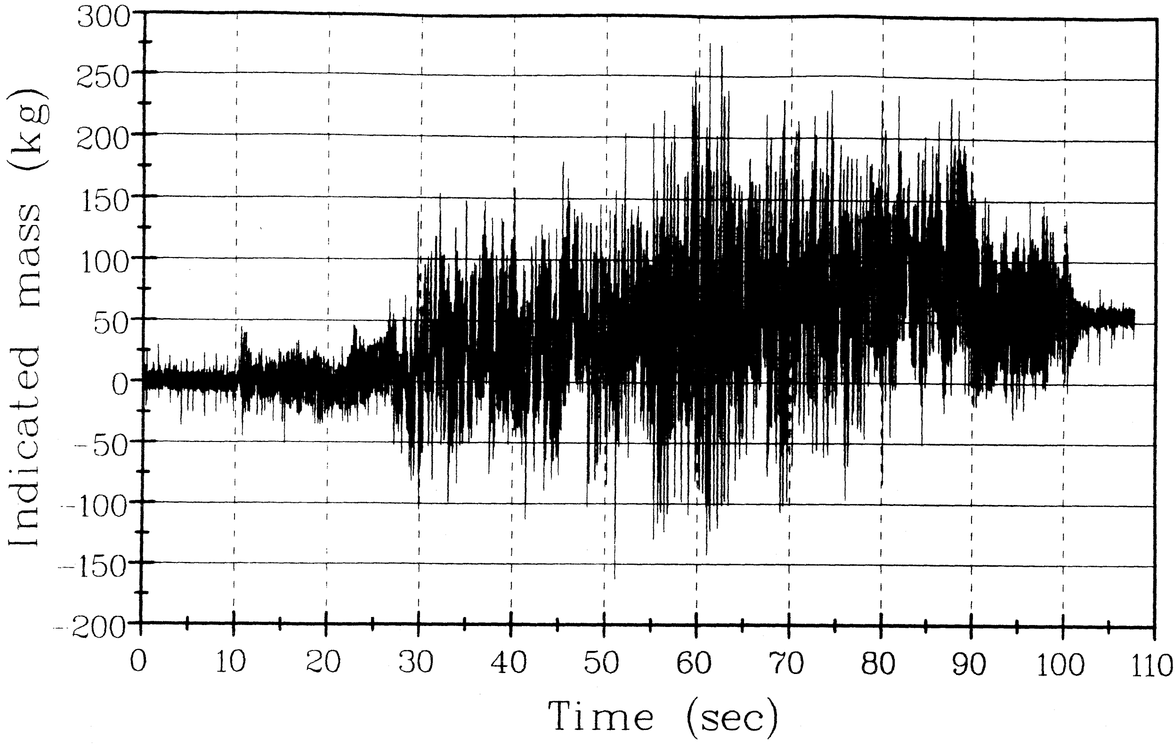

Figure 7: Indicated mass signal from the tongue of the baler (measurement freq. 200 Hz).

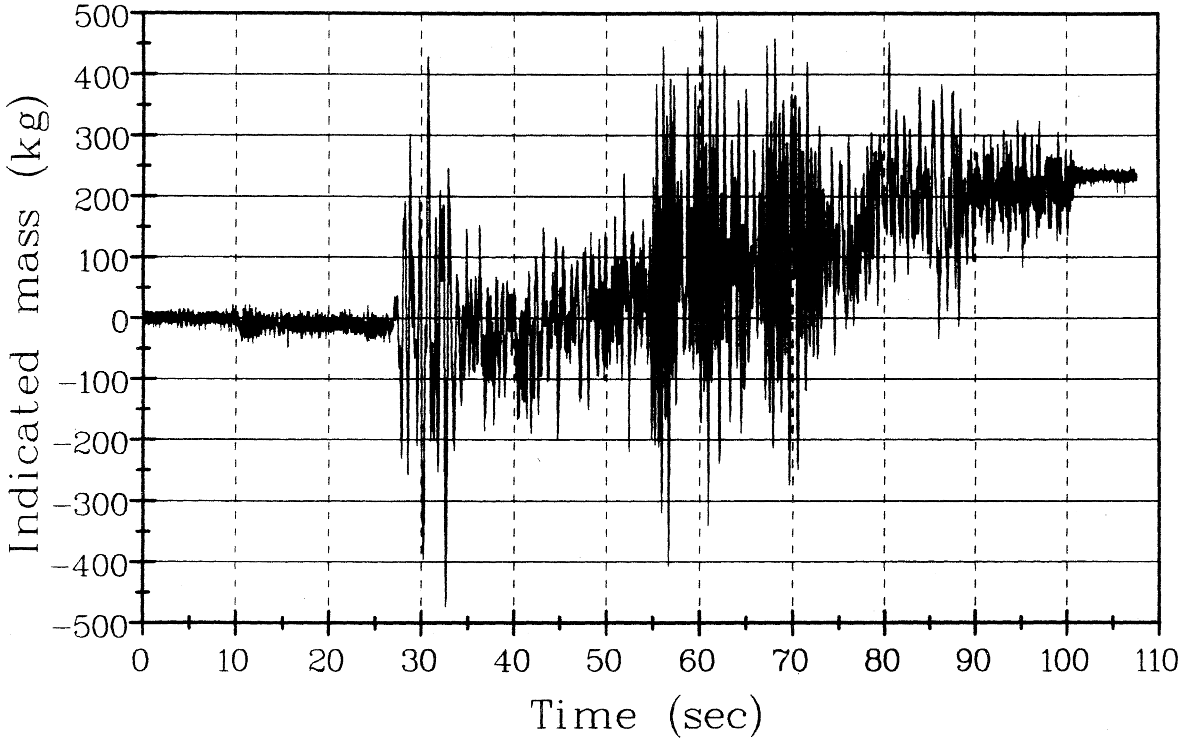

Figure 8: Indicated mass signal from the left side of the axle (measurement freq. 200 Hz).

The figures show the weight signals from the tongue and the left side of the axle during the period when a bale was made. Between 0 and 10 sec the tractor was not moving, but its engine was running and the PTO was turned off. At this stage the signal from the tongue already shows variations of ± 15 kg with peak values of up to ± 40 kg, the axle signals vary by around ± 20 kg. As soon as the PTO is turned on (after 10 sec), the variations increase even more. Also a signal drop at the left side of the axle can be seen. This is due to a load shift from the left to the right side of the axle caused by torque transmitted by the PTO shaft. When the baler started moving (after 25 sec) the variations greatly increased. Maximum deviations of more than 200 kg at the tongue and 400 kg at the axle occured.

There are different mathematical methods for smoothing signals such as the use of a running average or of band-pass filters. Analyses of this kind are still being conducted. An initial result is presented in Figure 9. It shows the smoothed indicated mass change of a bale after a running average calculation (with 500 data points) was performed. The curve is the sum of the smoothed signals from the tongue and from the left and right side of the axle. Still, the graph shows vibrations which leads to deviations of ± 15 kg for the indicated mass.

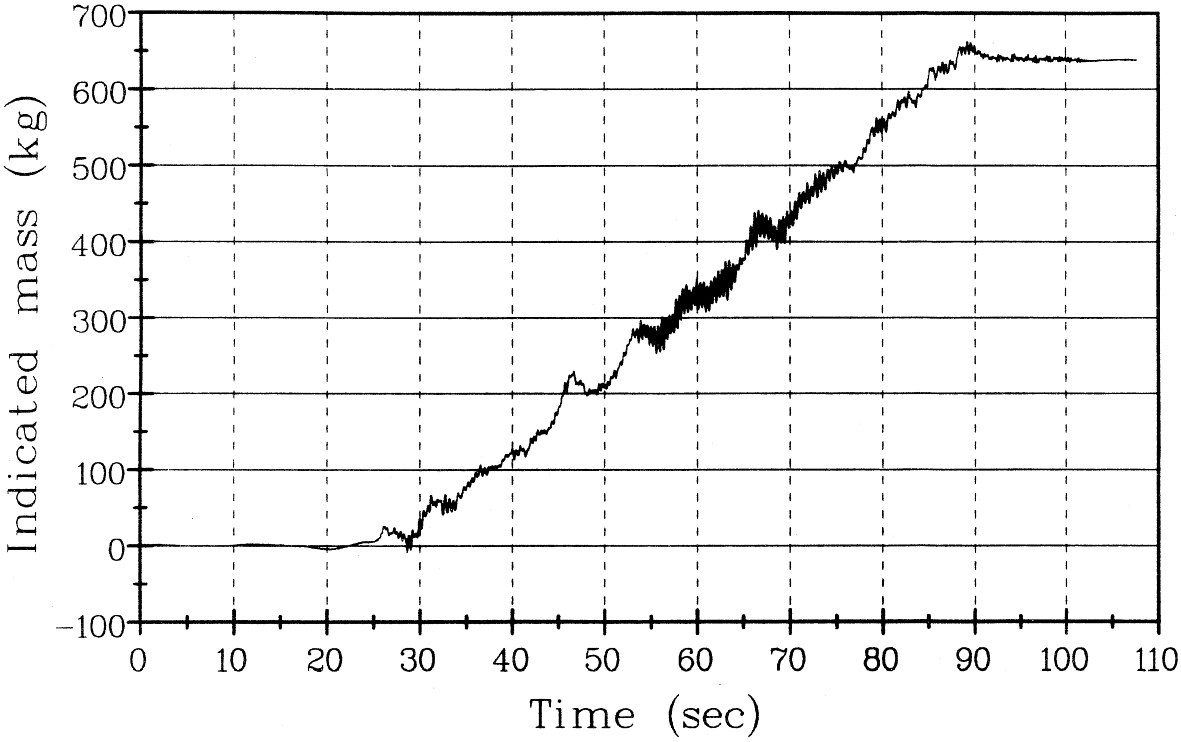

Figure 9: Smoothed indicated mass signal from round baler (running average with 500 data points).

Besides the mathematical methods other procedures were applied for determining the actual masses. The vertical accelerations detected (besides gravity) were used for getting better mass data. Theoretically, a strain gage should provide the actual weight if there were no additional accelerations other than gravity. In Figure 10 the results are shown for driving on a field with the baler without picking up forage, which means the bale mass equals zero.

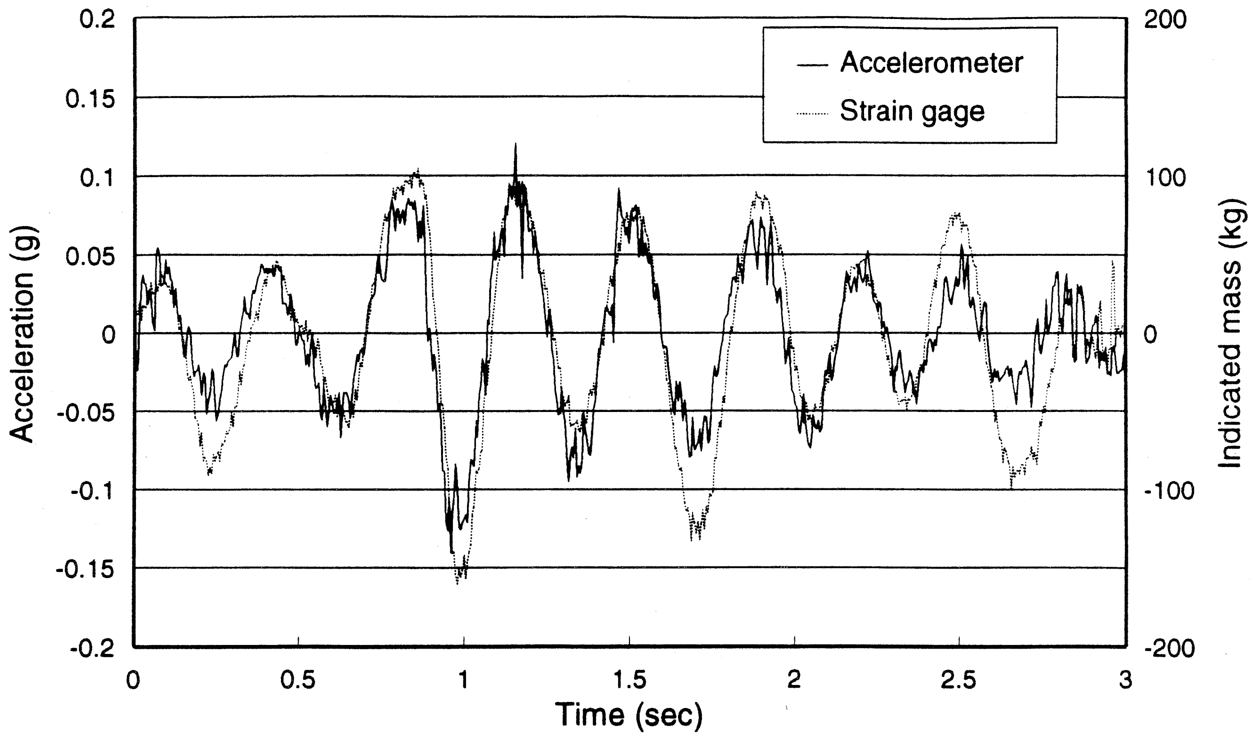

Figure 10: Acceleration and indicated mass signal from the left side of the axle.

In more than 50 % of the cases when the vertical acceleration is zero, the indicated mass is correctly determined to be zero. The search for methods for increasing the number of correct readings is still being conducted.

Conclusions

With the measurement system installed, and with the analysis algorithms developed, machinery parameters can be gathered and processed automatically with high quality.

Operating times can be determined automatically with a high accuracy. In combination with the trace of the machinery, trace maps of operation patterns can be prepared and be used for work management improvement.

The mass detection on-the-go for local yield monitoring is still not accurate enough. But there are promising approaches, which require further investigations.

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Appendix

Figure 6: Trace map of the pattern of operation.