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Title:

GPS-Based Analysis and Visualization of Machinery Use and Working Time for Harvesting Operations

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Summary:

Based on GPS and appropriate sensors in vehicles and implements, a system for the automatic gathering of data on working time and machinery use was created. For analyzing these data, a special program ("SATAZA") was developed. The current version is able to analyze data from round balers and selfloading trailers. It can detect times for working elements, type of work and influence factors on working time requirement. The results are presented in graphical and table format and can be transferred to other software via appropriate interfaces. Working elements that cannot be detected by the program may be identified by the user with integrated analysis tools.

1. Introduction and Objectives

The currently employed finite time measurement techniques for farmers do not meet the requirements requested by an economical farm management. They do not allow a detailed acquisition, and the determined values are often uncertain or incorrect (BÖCKL 1988). A major reason for this is the working person, who is often not able to collect the data in a careful manner due to the work load. Suitable technical solutions for installation on agricultural machinery are not available (WILD 1998).

Such disadvantages could be avoided with causal time measurement techniques, but the need for an additional person to record the data makes them too cost-intensive to constitute a feasible solution for farmers wanting to gather data on working time. Thus, in recent years, much research has gone into developping systems which allow for an automatic acquisition of working time data with suitable technical devices which are installed in the vehicles and implements used and which do not require an additional person to record the data. (BILLER 1985; GAUTZ et al. 1989; AUERNHAMMER et al. 1990; WILD et al. 1994a, b) (Fig. 1).

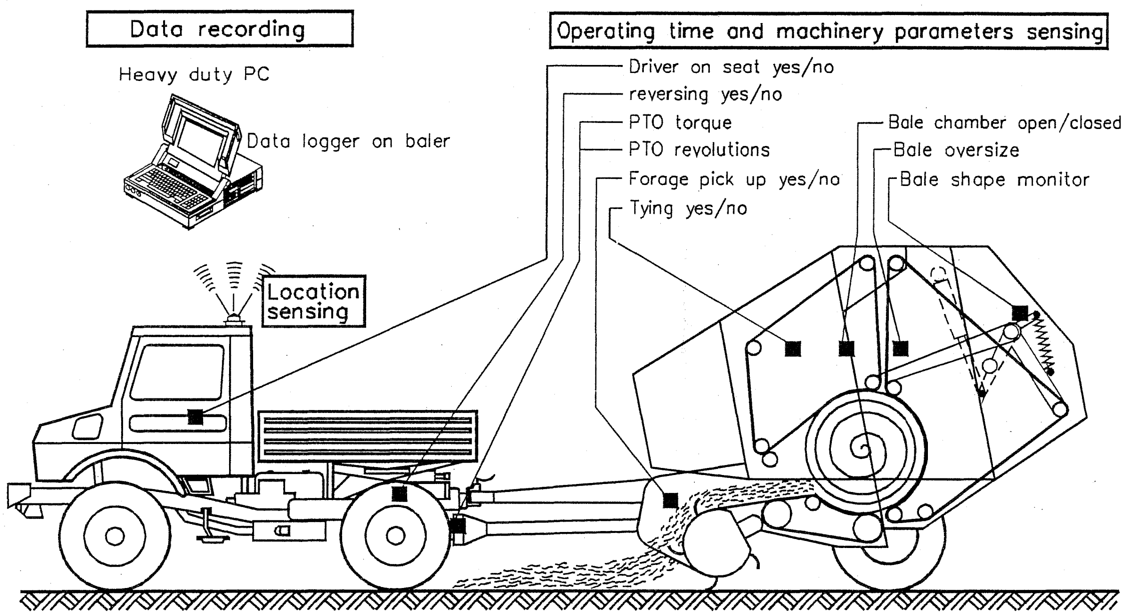

Figure 1: Sensors and acquisition system on tractor and round baler.

For agricultural uses outside of closed buildings, the satellite-supported positioning and navigation system GPS has proven an excellent basis for the acquisition of data on working time (AUERNHAMMER et al. 1995, WILD 1998).

Since there are are no special programs available at the moment for the analysis of working time data automatically recorded on files that include GPS positions, research at the Bavarian State Center for Agricultural Engineering at Freising has been geared towards the development of a software package for the analysis of such files.

This program was to allow for a rapid and easy evaluation of data, both manually and automatically, with manual analysis intended to function mainly as a way of corroborating automatically recorded results and of developing analysis algorithms for a fully automatized analysis process. The results were to be presented in a graphical and table format, with suitable interfaces allowing for data transfer to the construction program *AutoCad* (graphical/geographical analyses), harvest records (finite analyses) and specialized working time databanks (planning time calculations) such as *LISL* (AUERNHAMMER 1995). Additionally, the program was to facilitate the analysis of variables affecting working time required.

These prerequisites led to the development of the program *SATAZA* (satellite-assisted working time analysis). The version currently available allows an evaluation of data from round balers and selfloading trailers.

2. Program Structure

Algorithms for the identification of work and process elements are essential parts of the program. Most work or process elements are identified by means of multiple data units (WILD 1998). For example, a section is classified as picking up if

* a sensor (e.g. photoelectric guard) identifies crop on the pick-up
* the vehicle is moving and
* the power take-off shaft is running.

Some elements may be identified only if the work process is taken into account as well. Times for the individual types of work (effective time, auxiliary time etc.) may be obtained by the appropriate summation of respective work and process elements.

The program structure is modular, facilitating the insertion of different analysis algorithms (e.g. for different machines). Such an extensive modularity has been primarily achieved by means of object-oriented programming (STROUSTRUP 1987).

3. Analysis Results with *SATAZA*

The selection of a data file sets off automatic analysis ending with a display of results. The following examplifies analysis results from a hay harvest ("Grafwiese", 1.5 ha) with a round baler (Fig. 2).

The foreground shows the window for the distance traveled by the vehicle combination. Different colors mark off the work/process elements actually involved. All sections of the distance traveled may be viewed in close up.

The windows in the background show the results in a table format. The "log" window contains all identified work/process elements in order of appearance. The element name is followed by the number of the respective data line in the original file with which the element started. The next column shows progress time in minutes (down to 1/100 of a minute), the last column indicates the duration of the respective element. This window also includes the name of the analyzed file, the number of bales read and calculated from the file and various other information.

Next to the date of operation and the name of the data file, the "result" window first indicates the beginning, end and duration of the process recorded. This is followed by the sums for the duration, the distance traveled and the average speed of the recorded work/process elements. Values for each individual bale are shown also.

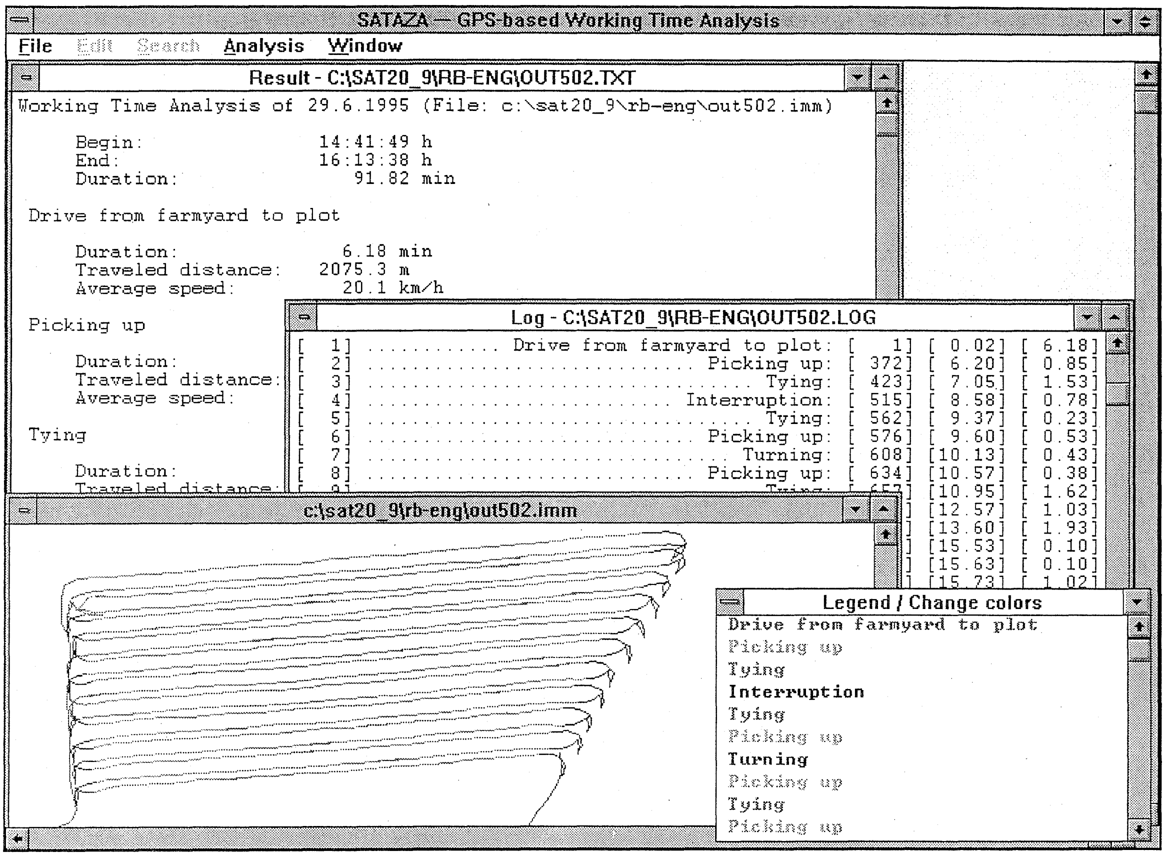

Figure 2: Display of results after analysis with SATAZA.

A so-called "AnalysisViewer" displaying the data file in an illustrative form is available for users desiring manual analysis (Fig. 3).

Convenient search functions facilitate the change of values, work elements or types of time. A viewing of the data and the distance traveled with the AnalysisViewer allows for a recapitulation of the entire work process and thus the determination of the beginning and end of individual work elements.

The results of manual analysis with *SATAZA* and the subsequent classification according to types of work and total time are currently calculated with the spread sheet program *Excel* and displayed as a formatted table (Tab. 1).

The results are structured hierarchically in three analysis levels, with the values of level 3, the element level, originating from *SATAZA*, those of the two levels above from calculations in *Excel*. Thus, the table contains detailed and aggregated time specifications.

On the basis of the processed data and the recorded distance traveled, most variables affecting working time requirement may be calculated. Apart from distance and speed, length and form of field, actual working width, work form and type of turn may be deduced.

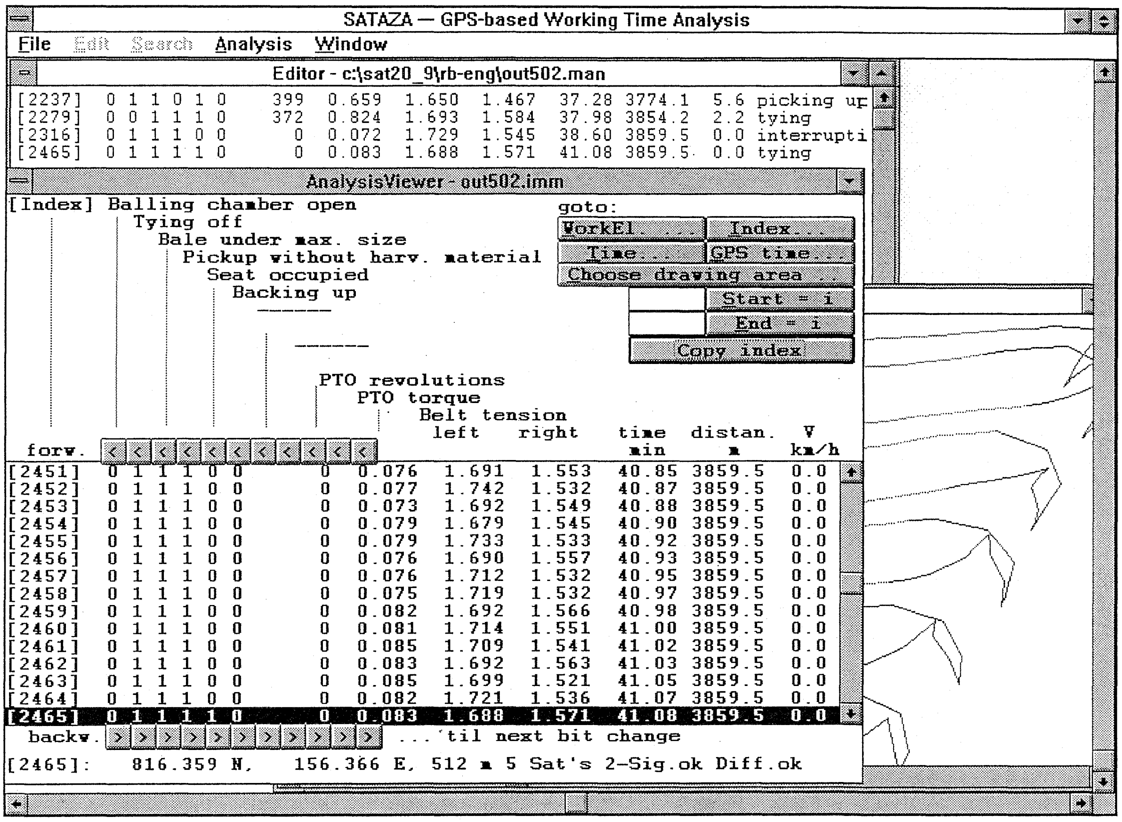

Figure 3: Manual analysis with the AnalysisViewer in SATAZA.

4. Accuracy of Analysis

A comparison with reference times based on measurements with a stopwatch serves to verify both the accuracy of the automatized data acquisition and the manual working time analysis with *SATAZA* (Tab. 2).

The times obtained show that the automatically recorded data contains all necessary information for quite a precise determination of the duration of individual time segments. The greatest differences between times recorded with the stop watch and the results of a manual analysis with *SATAZA* are to be found on the element level. On the levels above, the differences are offset by an increasing degree of summation so that the difference with respect to total time is minimal.

The differences in time are primarily due to problems with the recognition of crop pick up. As indicated in Table 2, the difference of 58 cmin at crop pick up corresponds to the amount of time missing at tying (-43 cmin) and turning (-16 cmin). The main reason for overstated values at crop pick up is the exact determination of the end of crop pick up and the beginning of tying. At this change of element, the tractor driver stops to reverse the vehicle. As an exact analysis has shown, the person recording time with a stop watch considered crop pick up finished as soon as the tractor stopped but before reversing. The pick-up of the baler, however, continues to draw crop from the swath even when the tractor is stopped, resulting in an interruption of the photoelectric guard beam which, in turn, signalizes crop pick up in the automatically recorded data. Thus, the differences in time are primarily inherent in the system.

Table 1: Working times determined with SATAZA's module for manual analysis (round baling, Grafwiese, 29. 06.1995).

Analysis Level	Section							
1	Total Time	Total Time 91.77 min						
2	Kind of Work	Working Time 87.72 min				Interruption Time 4.05 min		
		Effect. Time	Aux. Time	Prep. Time	Driv. Time	Technical	Organizat.	Personal
		66.99 min	7.61 min	3.24 min	9.88 min	---	---	---
3	Work / Process Element	Picking up	27.42 min			Interruption	4.05 min	
		Tying	39.57 min					
		Turning	7.61 min					
		Twine Replenishment	--- min					
		Start-up Baling	1.00 min					
		Start-up Driving	2.24 min					
		Drive Farmyard - Plot	5.00 min					
		Drive Plot - Farmyard	4.88 min					

Table 2: Differences of working times detected with stopwatch and SATAZA (manual analysis, Grafwiese, 29.06.1995.

Section	Measured with Stopwatch (min)	Share of Total Time (%)	Detected with SATAZA (manually) (min)	Difference abs. (min)	Difference rel. (%)	Difference as Share of Total Time (%)
Total Time	91.81	100.0	91.77	0.0	0.0	0.0
Working Time	87.79	95.6	87.72	-0.1	-0.1	-0.1
Interruption Time	4.02	4.4	4.05	0.0	0.7	0.0
Effective Time	66.84	72.8	66.99	0.2	0.2	0.2
Auxiliary Time	7.77	8.5	7.61	-0.2	-2.1	-0.2
Preparation Time	3.24	3.5	3.24	0.0	0.0	0.0
Driving Time	9.94	10.8	9.88	-0.1	-0.6	-0.1
Time for Picking up	26.84	29.2	27.42	0.6	2.2	0.6
Time for Tying	40.00	43.6	39.57	-0.4	-1.1	-0.5
Time for Turning	7.77	8.5	7.61	-0.2	-2.1	-0.2
Time for Twine Replenishment	0.00	0.0	---.--	---.--	---.--	---.--
Time for Baling Preparation	1.04	1.1	1.00	0.0	-3.8	0.0
Time for Drive Preparation	2.20	2.4	2.24	0.0	1.8	0.0
Time for Drive Farmyard - Plot	5.01	5.5	5.00	0.0	-0.2	0.0
Time for Drive Plot - Farmyard	4.93	5.4	4.88	-0.1	-1.0	-0.1

With automatic analysis with *SATAZA*, results frequently show greater deviation from reference times than with manual calculation (Tab. 3).

Table 3: Working times detected with stopwatch and SATAZA (automatic analysis, Grafwiese, 29.06.1995

Section	Measured with Stopwatch (min)	Share of Total Time (%)	Detected with SATAZA (automatically) (min)	Difference abs. (min)	Difference rel. (%)	Difference as Share of Total Time (%)
Total Time	91.81	100.0	91.83	0.0	0.0	0.0
Working Time	87.79	95.6	88.01	0.2	0.3	0.2
Interruption Time	4.02	4.4	3.82	-0.2	-5.0	-0.2
Effective Time	66.84	72.8	65.94	-0.9	-1.3	-1.0
Auxiliary Time	7.77	8.5	10.62	2.9	36.7	3.1
Preparation Time	3.24	3.5	---.--	---.--	---.--	---.--
Driving Time	9.94	10.8	11.45	1.5	15.2	1.6
Time for Picking up	26.84	29.2	27.43	0.6	2.2	0.6
Time for Tying	40.00	43.6	38.51	-1.5	-3.7	-1.6
Time for Turning	7.77	8.5	10.62	2.9	36.7	3.1
Time for Twine Replenishment	0.00	0.0	---.--	---.--	---.--	---.--
Time for Baling Preparation	1.04	1.1	---.--	---.--	---.--	---.--
Time for Drive Preparation	2.20	2.4	---.--	---.--	---.--	---.--
Time for Drive Farmyard - Plot	5.01	5.5	6.18	1.2	23.4	1.3
Time for Drive Plot - Farmyard	4.93	5.4	5.27	0.3	6.9	0.4

The total time obtained for crop pick up at the Grafwiese differs from the value obtained with the stopwatch by 59 cmin, but there is practically no difference to the result of the manual analysis (1 cmin). The reasons for the difference between the times obtained with automatic calculation and stop watch results correspond to the reasons for the difference between stop watch times and manual analysis with *SATAZA*, i.e. the different definition of the end of crop pick up and the beginning of tying inherent in the system.

The high deviations in total time for turning (36.7%) and tying (-3.7%) originate mainly with the last bale. This bale was different from previous ones in that the tying process was set of manually by the driver and not by the automatic tying process of the baler. Manual set off became necessary since the bale did not reach the size required for automatic set off. Since there were no signals indicating the start of the automatic tying process, *SATAZA* was not able to identify the manually set off tying process. On the basis of existing facts, *SATAZA* classified this period as turning. This mistake could be avoided with the insertion of a modified algorithm for the last bale to identify manual tying.

Another major reason for the time differences obtained is the lack of an algorithm to identify preparation. With the current *SATAZA* analysis process, this leads to a faulty increase in travelling time for the distances traveled to and from the field, as well as an effect on the times for other work elements with the last bale. Therefore, the next version of *SATAZA* will include preparation time in the analysis.

The difference in interruption time originated with one of the three interruptions that occurred: *SATAZA* identified the duration of this interruption as 20 cmin too short, since the automatic analysis considered the interruption ended when the driver returned to his seat, while the interruption in reality only ended with the beginning of pick up. The algorithm will have to be extended in this respect.

5. Conclusions

SATAZA opens up a possibility for a rapid, user-friendly working time analysis yielding a diversity of results. Modules still missing for a fully automatic analysis may currently be obtained with manual analysis with *SATAZA*.

The automatic recording of data and the automatic analysis reduce the effort needed for working time analysis to a minimum. Our own results do not allow conclusions as to whether every file may always be analyzed completely. We assume, however, that a finite analysis is always an option. With research analyses, it should be possible to skip a file that cannot be analyzed due to the wealth of data available. Additionally, with extensive amounts of data, occasional unidentified mistakes are offset to a large degree by statistical extrapolations.

A fact that has not been considered in the past with respect to automatic analysis is the information inherent in the positions obtained. As is obvious from manual analysis, analysis possibilities could be substantially extended. It must be taken into account, however, that the integration of the variables "position" or "vehicle track" will be very labor-intensive. At the moment, it would probably be more advantageous if further development and refinement of the program would focus more on to the integration of the working process.

6. References

Auernhammer, H.: Die Rolle von LISL in der Arbeitszeitkalkulation 2000. In: Agrartechnische Berichte No. 26: 10. Arbeitswissenschaftliches Seminar am 23. und 24. Oktober 1995. Hohenheim: Institut für Agrartechnik 1995, p. 35-46

Auernhammer, H. und J. Rottmeier: Ermittlung der Arbeitszeitbedarfes auf neuen Wegen. Landtechnik 45 (1990), No. 4, p. 161-163

Auernhammer, H., K. Wild und C. Paul: GPS als Grundlage zur automatisierten Arbeitszeiterfassung bei Feldarbeiten. In: Agrartechnische Berichte No. 26: 10. Arbeitswissenschaftliches Seminar am 23. und 24. Oktober 1995. Hohenheim: Institut für Agrartechnik 1995, p. 155-165

Biller, R.H.: Aufbau und Einsatz eines Datenerfassungssystems für Ackerschlepper. Grundlagen der Landtechnik 35 (1985), No. 4, p. 97-104

Böckl, M.: Ermittlung vereinfachter Arbeitszeitbedarfsfunktionen für die Feldarbeit aus computergestützten Arbeitstagebuchaufzeichnungen. Diplomarbeit: Institut für Landtechnik Weihenstephan 1988

Gautz, L.D., W.J. Chancellor and J.W. Rumsey: Automatic computer records of farm machinery use. ASAE Paper 89-1020 (1989)

Stroustrup, B.: C++. Bonn, Reading (Mass.), New York: Addison-Wesley 1987

Wild, K. and H. Auernhammer: Automatisierte Prozeßdatenerfassung bei elektronisch gesteuerten Arbeiten in der Außenwirtschaft. In: KTBL Arbeitspapier 175: Elektronikeinsatz in der Außenwirtschaft. Darmstadt: KTBL 1994a, p. 196-199

Wild, K., H. Auernhammer and J. Rottmeier: Automatic data acquisition on round balers. ASAE Paper 94-1582 (1994b)

Wild, K.: Satellitengestützte Arbeitszeiterfassung und Ertragsermittlung in Rundballenpressen. Ph.D.-Thesis, Freising: Institut für Landtechnik 1998