Time studies based on automatic data collection

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Summary

Up until today most time studies of forest machines have been based on manually collected data with a person being present in the cabin of the machine or standing outside the machine registering a large number of different events or work elements. The idea of trying to use data from the control system of harvesters and forwarders in order to e.g. decrease costs, increase number of machines in a study, and simplify time studies have been studied and discussed frequently during the last decade.

A study with two harvesters was carried out jointly by Skogforsk, SCA and John Deere in the autumn of 2013. The objective was to compare automatic with traditional manual data collection. Is it possible to implement algorithms which give a result from automatic data collection that is comparable with traditional data collection? Do both methods give the same ranking and trends?

Events registered in a TimberLink data set was used together with standardized hpr-files (StanForD2010). The machine events registered by the harvesters were ”Driving”, ”BoomSleew”, ”GrappleControlOpen”, ”GrappleControlClose”, ”FellCut”, ”Feeding”, ”LogCut” and ”StemComplete”. The hpr-file included a time stamp for each stem. Stem volume, species, dbh and number of logs was extracted per stem from the hpr-files.

An algorithm for calculating work elements based on TimberLink and hpr-data was developed in the study. The manual vs. automatic time studies gave similar results with only minor differences, giving the same ranking and average boom cycles. It is thus possible to use automatic data collection in future time studies.

Keywords: time studies, harvester, automatic data collection

Background

Historically time studies of forest machines in Scandinavia have been based on manually collected data with a person being present in the cabin of the machine or standing outside the machine registering a large number of different events or work elements (Anon 1978, Anon 1969). The idea of trying to use data from the control system of harvesters and forwarders have been studied and discussed in order to e.g. decrease costs, increase number of machines in a study and simplify data collection (Kariniemi & Vartiamäki, 2007, Arlinger & Jönsson, 2013). Some basic harvester studies using automatically collected data were carried out in the early 90’s in Sweden (Brunberg, 1991). However, no detailed technical documentation is available from these tests.

Objective

The main objective of the SCA/JohnDeere/Skogforsk study was to evaluate how a large harvester (JD 1470E) performed versus a small harvesters (JD 1170 E) in two separate stands (small mean stem volume vs large mean stem volume) in order to help SCA in deciding the composition of their harvester fleet. What number of large sized harvesters are needed vs medium and small sized harvesters (Arlinger et al, 2014)?

A secondary objective which is covered by this document was to test the possibilities of automatic data collection versus traditional manual data collection. Is it possible to implement algorithms which give a result from automatic data collection that is comparable with the traditional data collection (described by Arlinger & Jönsson 2013)? Do both methods give the same ranking and trends?

Material

A list of suitable machine events for automatic data collection has been described by Arlinger & Jönsson (2013). The possibility to collect these events (table 1) was discussed with John Deere in August 2013 as well as the possibility to connect this information with production data from hpr-files.

Table 1. Relevant machine events during harvester time studies.

Machine events – Harvester
Wheels moving
Lincage movement
Felling cut
Log cut
Feed rollers moving (feeding)
Tilt up
Tilt down
Knives opened
Knives closed

It was decided to collect two separate datasets during the study, a Timbelink dataset and an hpr dataset. In both cases some modifications had to be done to the Timberlink and Timbermatic softwares by John Deere.

The productivity study was designed in order to compare a large harvester with a small harvester with two different operators in two types of stands (Arlinger et al, 2014). Operator A being an experienced operator of the large harvester (JD1470E) and operator B being an experienced operator of the smaller harvester (JD1170E). The 8 different sub-studies are described in table 2.

Table 2. Relevant machine events during harvester time studies.

Harvester	**Operator**	**Type of stand**	**Date**
JD 1470E	A	Large mean stem volume	2013-01-02
JD 1470E	B	Large mean stem volume	2013-09-30
JD 1470E	A	Small mean stem volume	2013-10-09

JD 1470E	B	Small mean stem volume	2013-10-08
JD 1170E	A	Large mean stem volume	2013-01-01
JD 1170E	B	Large mean stem volume	2013-01-03
JD 1170E	A	Small mean stem volume	2013-10-07
JD 1170E	B	Small mean stem volume	2013-10-04

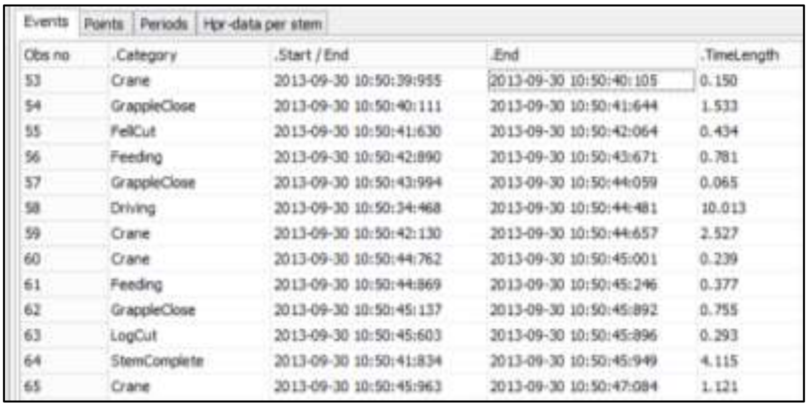
<u>TIMBERLINK DATASET</u>

The data set generated by TimberLink included a number of events available in the TimberLink database already before the study was planned. However, this dataset was specifically developed for this study. The events are partly a subset of the events described in table 1 (“Tilt up/down” excluded). There was also an additional Timberlink event, StemComplete, that was deemed to be highly relevant and therefore added to the dataset. A complete list of all events is included in table 3. The time when each event ended as well as the time span for each event was registered in the xml-file generated by TimberLink. An example of the data is included in figure 1.

Table 3. Events registered in TimberLink data set. The exact technical definition of each event is presently not known by Skogforsk.

Machine events
Driving
BoomSleew
GrappleControlOpen
GrappleControlClose
FellCut
Feeding
LogCut
StemComplete

Figure 1.Example of Timberlink events as presented in application for analysing automatically collected time study data.



Events | Points | Periods | Hpr-data per stem

Obs no	.Category	.Start / End	.End	.TimeLength
53	Crane	2013-09-30 10:50:39:955	2013-09-30 10:50:40:105	0.150
54	GrappleClose	2013-09-30 10:50:40:111	2013-09-30 10:50:41:644	1.533
55	FellCut	2013-09-30 10:50:41:630	2013-09-30 10:50:42:064	0.434
56	Feeding	2013-09-30 10:50:42:890	2013-09-30 10:50:43:671	0.781
57	GrappleClose	2013-09-30 10:50:43:994	2013-09-30 10:50:44:059	0.065
58	Driving	2013-09-30 10:50:34:468	2013-09-30 10:50:44:481	10.013
59	Crane	2013-09-30 10:50:42:130	2013-09-30 10:50:44:657	2.527
60	Crane	2013-09-30 10:50:44:762	2013-09-30 10:50:45:001	0.239
61	Feeding	2013-09-30 10:50:44:869	2013-09-30 10:50:45:246	0.377
62	GrappleClose	2013-09-30 10:50:45:137	2013-09-30 10:50:45:892	0.755
63	LogCut	2013-09-30 10:50:45:603	2013-09-30 10:50:45:896	0.293
64	StemComplete	2013-09-30 10:50:41:834	2013-09-30 10:50:45:949	4.115
65	Crane	2013-09-30 10:50:45:963	2013-09-30 10:50:47:084	1.121

Observe that the TimberLink data is encrypted which means that the raw data is only available using a JohnDeere specific decoding software.

HPR-FILES

Production data was generated in hpr-files as defined by StanForD2010, version 2.1 (Arlinger et al 2012). The hpr-file generation was slightly modified for this study in order to include the optional element HarvestDate. Stem volume, species, dbh, stem length and number of logs was extracted for each stem from the hpr-files (figure 2).

Figure 2.Example of production data (hpr-file) as presented in application for analysing automatically collected time study data.

Events | Points | Periods | Hpr-data per stem

StemKey	StemNumber	m3sub	totLogLength	DBH	HarvestDate
15094100	1	0.923	1995	382	2013-09-30 10:50:30:167
15094200	2	0.02	465	86	2013-09-30 10:50:42:954
15094300	3	0.432	1636	291	2013-09-30 10:51:01:016
15094400	4	0.228	1323	226	2013-09-30 10:51:17:434
15094500	5	0.288	1335	239	2013-09-30 10:51:31:313
15094600	6	0.538	1905	287	2013-09-30 10:51:54:684
15094700	7	0.383	1589	233	2013-09-30 10:52:19:867

Methods

ADJUSTING RAW DATA

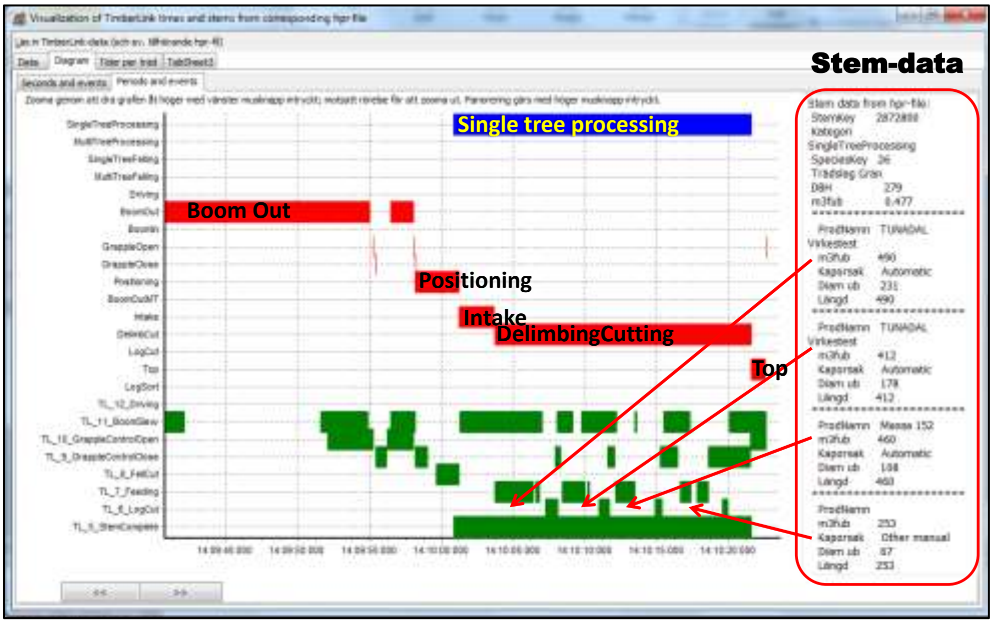
The times registered in the hpr-file (by Timbermatic software) were not continuously synchronized with the times registered in the TimberLink data set. This meant that the difference between the HarvestDate (hpr-file) and the end of StemComplete increased more or less linearly. An adjustment of HarvestDate (Hpr) was therefore carried out based on a simple linear regression.

BASIC CALCULATION ALGORITHMS

The algorithms for calculating the different work elements used in time studies was based on on Arlinger & Jönsson (2013). However, since the available data differed from what was assumed in that document some minor modifications had to be made.

Based on the algorithm the total time and the separate work elements per individual boom cycle were calculated as illustrated in figure 3.

Figure 3.Gantt chart describing one single boom cycle as well as some production data from an hpr-file. Green bars describe the original TimberLink data, red bars describe the calculated work elements and the blue bar describe the processing type according to the hpr-file.



<u>FILTERING</u>

A filtering of all stems was finally carried out before analysing the productivity. Only the stems fulfilling the following requirements were used in the analyses:

1. If HarvestDate is within start and end time of StemComplete
2. If “No of logs per stem in hpr” = “No of LogCut events in TimberLink”
3. If BoomCycleTime <= 100 seconds

Observe that the two first filtering methods were necessary since the linear increase in time differences between hpr and TimberLink was not perfectly linear. Using these two filtering methods all miss matches were deemed to be excluded. The third filtering was used in order to exclude stems that were harvested after a long down time or a long period of terrain travel since these stems would typically have very long and irrelevant boom cycles.

Stems with large volumes (>1.2 m3sub) were in some analyses excluded due to the fact that the stem volumes were calculated in different ways.

Results

The data has been analysed by both Brunberg (table 4 and 5) as well as by John Arlinger (figure 5-9). It can be noted that the boom cycles are slightly longer for the manual study (table 4) and that the coefficient (slope of the linear curve) is higher for the manual study (table 5). The diagrams (figure 4-8) illustrates that the slope of the curve based on manual data is not always greater than the automatically collected data.

Observe that not only the times when collecting data manually vs. automatically may differ, but also the stem volumes. This is due to the fact that, during manual data collection, only species and reference diameter (at 70 cm distance from stump) was registered and the stem volume was thereafter calculated and adjusted based on the total harvested volume.

Table 4. Collected data (cmin / boom cycle) for large and small sized stands (including multi-tree-harvested stems).

Work elements	Large mean stem volume		Small mean stem volume	
	Manual	Automatic	Manual	Automatic
Boom out	6,9	7,6	6,2	6,4
Positioning (Fällning)	3,5	3,1	2,8	2,7
Intake	5,7	4,4	3,8	3,1
Delimbing & cutting	16,5	18,7	11,1	12,2
Boom in	0,2	1,3	0,1	1
Top	1,5	1,5	0,9	1,4
Driving	3,7	0,8	3,0	0,5
Boom out 2	0,5	0	0,7	0
Boom out 3	0,1	0	0,1	0
Boom out 4	0	0	0	0
Other	1,4	1,4	0,8	1,5
G0-time	39,2	38,8	29,3	28,8
Mean stem volume (m3sub)	0,30	0,30	0,17	0,17

Figure 4) Boom cycle per stem (excluding multi-tree-harvested stems and stem volumes > 1.2 m3sub).

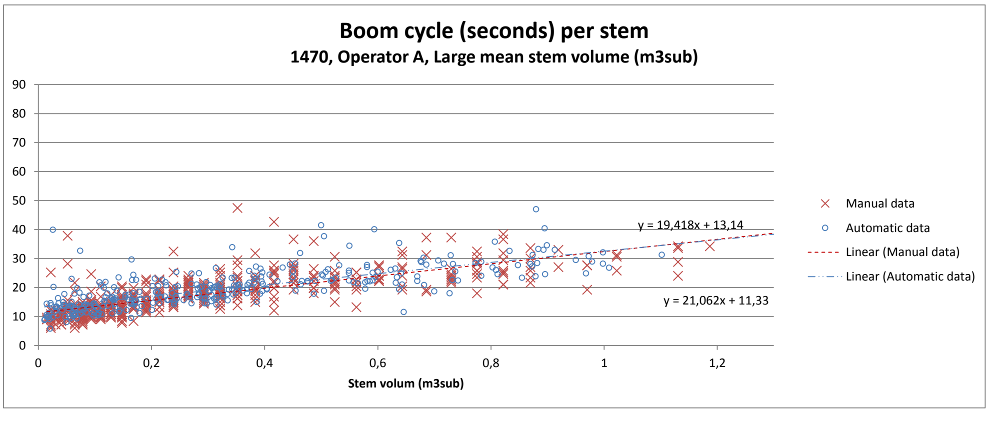


Figure 5) Boom cycle per stem (excluding multi-tree-harvested stems and stem volumes > 1.2 m3sub).

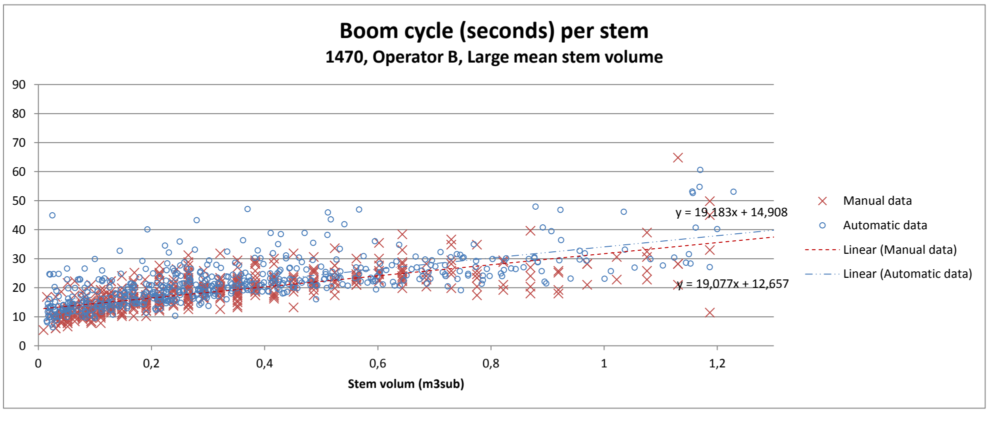


Figure 6) Boom cycle per stem (excluding multi-tree-harvesting and stem volumes > 1.2 m3sub).

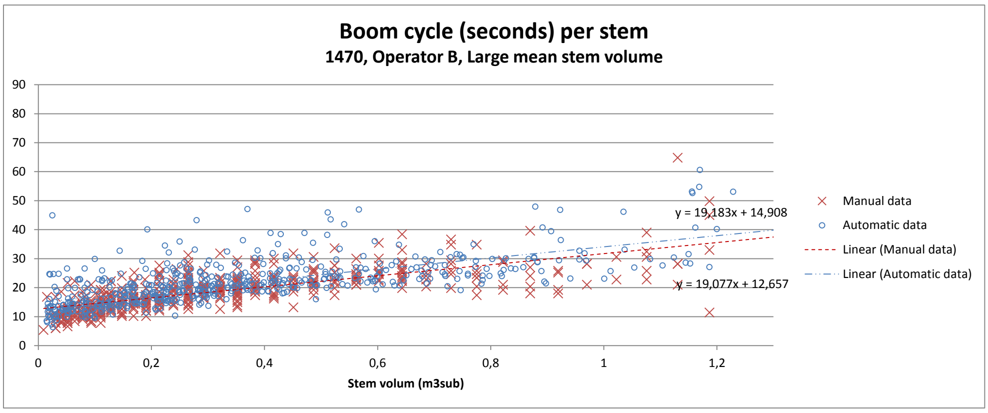


Figure 8) Boom cycle per stem (excluding multi-tree-harvested stems and stem volumes > 1.2 m3sub).

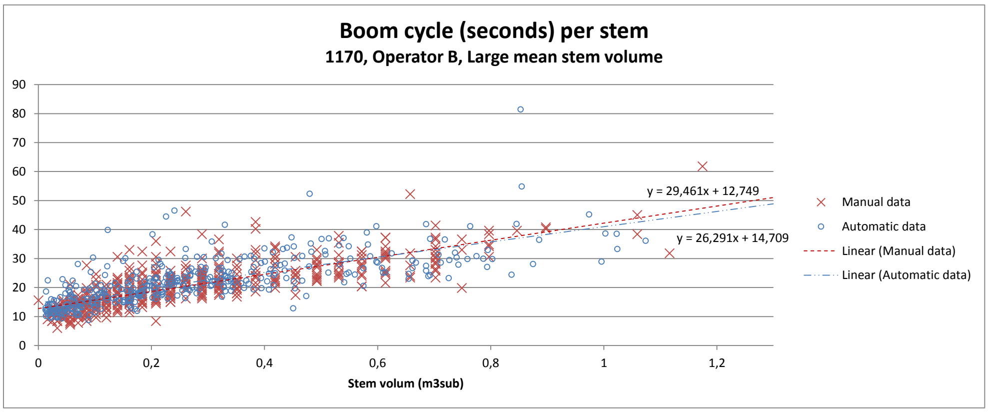


Table 5 Comparison of time functions (cmin/boom cycle) for manual and automatic studies.

Type of method	Large mean stem volume	Small mean stem volume
Manual	T=26,3+43V	T=22,0+48V
Automatic	T=27,1+39V	T=23,1+42V

Discussion

Results from the two types of time studies are comparable. The two types give the same ranking and the same average boom cycles. It is thus possible to use automatic data collection in future studies. However the results of these two different types of analyses will never be exactly identical. A time study person can draw conclusions based on verbal communication with the machine operator as well as by watching the operator's physical actions that is impossible to do when only utilizing automatically collected data. Both methods have their advantages and disadvantages.

Automatic data collection:

• can be done over long periods of times with minor "study effects" due to the fact that the harvester is run without any interferences from the personal doing the study

• probably have lower costs per hour since no time study personal need to be present

• has a high “time precision” meaning that it is possible to register the times with a very high resolution

• may not be fully comparable between different control systems (manufacturers) since the implementation of a function for registering events most certainly will depend on the layout of the software system as well as the hardware of the machine

• has a significant limitations when it comes to analysing the intent of the operator or effects of other conditions like climate, soil etc. It is thus important to have verbal communication with the operators and to study the individual sites also in case of using automatically collected data.

The timers were not continuously synchronized. This type of study would be greatly simplified if it would be possible to synchronize the timers of TimberLink and Timbermatic (hpr-file).

Filtering may have resulted in that certain “correct stems” were excluded. For example if the operator was forced to do more than one “log cut” in order to buck a single log. The filtering could perhaps be made more efficient by counting several log cuts with no intermediate feeding as one log cut.

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