Information support of the dynamics of system connectivity of wheel harvester operations

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Abstract. The article discusses the initial system dynamics of the connectivity of the work of the harvester head and the basic machine for the production of logs from the position of forming by processing the dynamics of work in a single functional space of time. On the basis of a deeper analysis of the dynamics of the production cycle of secondary raw materials and logs of the harvester head and the base machine in combination from the position of system analysis, a mathematical model for calculating the productivity of wood materials obtained from trees in a multi-operational sequential representation was built, performed by one harvester head. The total functional time of production of a unit of labor by the performed suboperations and its storage for all trees in the cycle becomes the main connecting parameter that allows us to represent the dynamics of the process. A solution is proposed to reduce the functional time for the operator of the harvester to make a decision on the production of logs of one or another quality and dimensional characteristics by using program for dynamic calculation and graphical representation of the output of finished products from a separate part of the tree trunk «STMLOGIC».

1. Introduction
The modern Scandinavian machine technology for the production of assortments in the cutting area (cut-to-length technology) consists of a harvester (wheel or track based), which performs tree felling, delimbing, cut-to-length, sorting of a micro-pack of logs at the first stage [1, 2], and the primary removal of logs by a wheeled forwarder on the second [3, 4]. From the standpoint of a systematic approach [5, 6] the system of forestry machines for the Scandinavian technology of logs production "harvester + forwarder" form a single technological structure linked by a single functional space minus the production time. The dynamics of the systemic connectivity of the work of the harvester head (HH) of wheel harvester and the base machine for the production of logs occurs in a single functional space of time.

Purpose of work. Increase in labor productivity based on optimization of the dynamics of the work of the wheel harvester and the base machine in a single functional space-time by implementing dependencies in the software of the wheel harvester.
2. Methods and Materials
The functional connectivity of the suboperations of the wheel harvester and the base machine is based on the timing of the operation of the harvester head Ponsse H7 and the base machine – the wheel harvester Ponsse Ergo 8W, assembled in 2018, 15826 operating hours, Ponsse Opti4G control system version 4.761, figure 1 [7, 8]. The data were obtained during the work of the wheel harvester on the Kortkeros area of the Eastern branch of Mondi SLPK JSC, quarter no. 100, plot no. typical natural-production conditions of the enterprise's lease base: mixed forest (species composition 30% aspen, 20% birch, 10% spruce, + pine), type of forest - blueberry, average tree volume $V_{hl, av} = 0.27 \text{ m}^3$, length of logs $l_c = 4 \text{ m}$.

Figure 1. Ponsse Opti4G GUI version 4.761.

Numerical representation and prediction of the length of the cut assortment, which is not clear and difficult to estimate for the operator in the face of a shortage of time to make a decision on the production of assortments of one or another quality and dimensional characteristics shows, figure 1.

The overall productivity of the timber harvesting phase is influenced by a large number of environmental factors, such as the inventory characteristics of plantations, natural production, climatic and relief conditions of the lease base of a logging enterprise, and also internal factors such as the state of the forest machine, its technical and technological readiness, the functionality used, as well as the qualifications, experience and motivation of the operator, the level of his digitalization.

The data read from the forest machine’s sensors is written into its on-board system. They are stored in various extensions, which allows you to structure the received data. The main files that store data about each cut tree are in STM format. The data in this file is built using the StanForD2010 standard.

To read STM files, various software products from manufacturers of forestry machinery and equipment (harvester heads, measuring systems, etc.) are used. Files in STM format can be used to study the data obtained during the work of the harvester.

To improve effective forest management in the face of risk and uncertainty, based on the best practices of the Scandinavian countries, the data obtained on harvested products from multi-operation forest machines should be analyzed.

Fragment of the location of packs of logs in the apiary after moving along the trail of the wheel harvester and the connectivity of the suboperations of the harvester head and the base machine for the production of logs is shown, figure 2.
3. Results and Discussion

Technological operations can be considered as a multi-step technological process of systemic HH connectivity (felling-delimbing-cut-to-length-sub-sorting-transition from one parking lot to another).

Fragment of the scheme of the sequential production process of logs and secondary raw materials of the wheel harvester is shown, figure 3.
Figure 3. Diagram of the sequential process for the production of assortments and secondary raw materials wheel harvester.

where,

- \( V_d \) – wood volume, m\(^3\).
- \( V_{ci} \) – log volume, \( i = 1 \ldots 3 \), m\(^3\).
- \( V_{b,c} \) – crown volume, m\(^3\).
- \( i \) – parking number, \( i = 1 \ldots n \).
- \( j \) – operation number, \( j = 1 \) (felling), \( j = 2 \) (delimbing), \( j = 3 \) (cut-to-length), \( j = 4 \) (crown production).
- \( k \) – the number of trees under cultivation at the parking lot \( k = 1 \ldots m \).
- \( l \) – the number of the log, in the figure 3, \( l = 1 \ldots 3 \).

In accordance with the scheme, the productivity for each operation:

- productivity of \( k \)-tree felling (\( P_{d1k} \)) can be estimated by formula:

\[
P_{d1k} = \frac{V_{d1k}}{T_{d1k}},
\]

where,

- \( V_{di} \) – volume of one tree, m\(^3\).
- \( T_{dijk} \) – production time when felling \( k \) – wood, sec.

And, accordingly, the functional time \( T_{Fd1k} \) (production time per unit volume of wood products) can be estimated a formula:

\[
T_{Fd1k} = \sum_{k=1}^{m} \frac{T_{d1k}}{V_{d1k}}.
\]

And the productivity of trees at the \( i \)-stop (\( P_{Fd1k} \)) is described by the expression:

\[
P_{Fd1k} = \left( \sum_{k=1}^{m} \frac{T_{d1k}}{V_{d1k}} \right)^{-1}.
\]

The productivity (\( P_i \)) of the obtained wood material and the functional time (\( T_i \)) of the production of a unit of wood volume in steps, respectively, is equal to:

- wood material (end product: logs and felling residues, second stage):
  - the first log \( P_{1c12k} \) can be estimated a formula:

\[
P_{1c12k} = \frac{V_{1c12k}}{t_{1c12k} + t_{1c13k}}.
\]
– functional time of obtaining a unit of volume of wood of the first log $T_{1ci2k}$ can be estimated by formula:

$$T_{1ci2k} = \frac{t_{1ci2k} + t_{1ci3k}}{V_{1ci2k}}. \quad (5)$$

– productivity of felling residues of the first log $P_{1poci2k}$ can be estimated by formula:

$$P_{1poci2k} = \frac{V_{1i2k}}{t_{1ci2k}}. \quad (6)$$

– functional time of obtaining a unit of felling residues of the first log $T_{1poci2k}$ can be estimated by formula:

$$T_{1poci2k} = \frac{t_{1ci2k}}{V_{1ci2k}}. \quad (7)$$

– the second log $P_{2ci2k}$ can be estimated by formula:

$$P_{2ci2k} = \frac{V_{2ci2k}}{t_{2ci2k} + t_{2ci3k}}. \quad (8)$$

– functional time of obtaining a unit of volume of wood of the second log $T_{2ci2k}$ can be estimated by formula:

$$T_{2ci2k} = \frac{t_{2ci2k} + t_{2ci3k}}{V_{2ci2k}}. \quad (9)$$

– productivity of felling residues of the second log $P_{2poci2k}$ can be estimated by formula:

$$P_{2poci2k} = \frac{V_{2i2k}}{t_{2ci2k}}. \quad (10)$$

– functional time of obtaining a unit of felling residues of the second log $T_{2poci2k}$ can be estimated by formula:

$$T_{2poci2k} = \frac{t_{2ci2k}}{V_{2ci2k}}. \quad (11)$$

And the performance of the final log $P_{3ci2k}$ can be estimated by formula:

$$P_{3ci2k} = \frac{V_{3ci2k}}{t_{3ci2k} + t_{3ci3k}}. \quad (12)$$

– functional time of obtaining a unit of volume of wood of the final log $T_{3ci2k}$ can be estimated by formula:

$$T_{3ci2k} = \frac{t_{3ci2k} + t_{3ci3k}}{V_{3ci2k}}. \quad (13)$$

– productivity of cutting residues of the final log $P_{3poci2k}$ can be estimated by formula:
\[ P_{3poci2k} = \frac{V_{3c2k}}{t_{3c2k}}. \] (14)

- functional time of obtaining a unit of cut residues of the final log \( T_{3poci2k} \) can be estimated by formula:

\[ T_{3poci2k} = \frac{t_{3c2k}}{V_{3c2k}}. \] (15)

- obtaining 1 m³ of wood crown material (final product: crown, third stage) \( P_{oi4k} \) can be estimated by formula:

\[ P_{oi4k} = \frac{V_{oi4k}}{t_{oi4k}}. \] (16)

- functional time of obtaining 1 m³ of woody crown material (final product: crown, third stage) \( T_{oi4k} \) can be estimated by formula:

\[ T_{oi4k} = \frac{t_{oi4k}}{V_{oi4k}}. \] (17)

On the basis of formulas 5, 9, 13, the functional production time of 1 m³ of round timber \( T_{HH} \) of wheel harvester at the \( i \)-parking lot is equal to:

\[ T = \frac{t_{1c2k} + t_{1c3k}}{V_{1c2k}} + \frac{t_{2c2k} + t_{2c3k}}{V_{2c2k}} + \frac{t_{3c2k} + t_{3c3k}}{V_{3c2k}}. \] (18)

And the productivity of \( P \) logs in this parking lot is equal to:

\[ T = \left( \frac{t_{1c2k} + t_{1c3k}}{V_{1c2k}} + \frac{t_{2c2k} + t_{2c3k}}{V_{2c2k}} + \frac{t_{3c2k} + t_{3c3k}}{V_{3c2k}} \right)^{-1}. \] (19)

Functional time of production of felling residues \( T_{b.c.} \) equally:

\[ T_{b.c.} = \frac{t_{1c2k} + t_{2c2k} + t_{3c2k}}{V_{1c2k} + V_{2c2k} + V_{3c2k}}. \] (20)

And the productivity of felling residues \( P_{b.c.} \) in this parking lot is equal to:

\[ P_{b.c.} = \left( \frac{t_{1c2k} + t_{2c2k} + t_{3c2k}}{V_{1c2k} + V_{2c2k} + V_{3c2k}} \right)^{-1}. \] (21)

To improve the Ponsse Opti4G for wheel harvester software for the end user and reduce the time for making a decision on the production of an logs of one or another quality and dimensional characteristics on the basis of a multi-step technological process of system connectivity of the HH, a program of dynamic calculation and graphical representation of the finished product output from a separate part of the tree «STMLOGIC» [9].

These files are configured according to the StanForD2010 standard using the Python 3.7.9 [10, 11] programming language, each of them contains various codes of variables and their types, in accordance with which it is possible to correctly read the recorded dimensional and qualitative characteristics of
tree, as well as other informative forestry machine performance data for later analysis to improve work operations to increase the yield of round timber.

The program interface is shown, figure 4.

![Figure 4. «STMLOGIC» program interface.](image)

Purpose of the program: application for operators of multioperational forestry machines (wheel harvesters). Scope: analysis of the data obtained on the trees, logs (STM files) from the on-board computer of a multioperational forestry machine. Functionality: measuring the volume of the tree to the specified height and the percentage of bark content in the calculated volume; visually convenient display of the dimensional parameters of logs, including small logs (up to 0.1 m in length); tabular presentation of dimensional data for each log. Computer type: IBM PC-compatible PC. System requirements: OS Windows XP 32-bit or higher.

On the basis of a deeper analysis of the dynamics of the production cycle of secondary raw materials and logs of the HH and the base machine in combination from the position of system analysis, a mathematical model for calculating the productivity of wood materials obtained from trees in a multi-operational sequential representation was built: felling-delimbing-bucking-subsorting-transit from one parking lot to another, performed by one HH. In the complex under consideration, the productivity of the wheeled harvester is determined on the basis of the summation of the technological time of wood production.

The total functional time of production of a unit of labor by the performed suboperations and its storage for all trees in the cycle becomes the main connecting parameter that allows us to represent the dynamics of the process as a single deeply integrated production structure. On the basis of the developed mathematical model, a solution was proposed to reduce the functional time for the operator of the wheel harvester to make a decision on the production of logs of a particular quality and dimensional characteristics by using the Ponsse Ergo 8W PonsseOpti 4G version 4.761 program for dynamic calculation and graphical representation of the output of finished products from a separate part of the STMLOGIC tree (using data according to the StanForD2010 standard) instead of the user-friendly digital interface of the existing software. The use of a graphical representation contributes to the disclosure of the system dynamics of the connectivity of the HH and the base machine for the production of logs by improving the processing of the dynamics of work in a single functional space of time by reducing the time for making decisions on the implementation of dependencies in the wheel harvester software as a multi-step technological process of the system connectivity of the HH (cutting-delimbing-bucking-subsorting-transition from one parking lot to another).

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