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# TURNING A WINCH SKIDDER INTO A SELF-DATA COLLECTION MACHINE USING EXTERNAL SENSORS: A METHODOLOGICAL CONCEPT

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***Abstract:*** *The results of forest production studies are crucial for maintaining the competitive edge of forest industries. Yet, their traditional implementation involves substantial resources including financial ones leading frequently to the limitation of field sampled data. A promising way to collect the needed data while keeping low the amount of resources needed is that of using external sensors able to substitute partially or totally the human presence in the field. The usefulness of built-in sensors to collect production data has already been demonstrated for highly-mechanized cut-to-length forest equipment. While being extensively used in many parts of the world, most of the winch skidders lack such a sensor system. This paper describes a methodological concept for field data collection by equipping the winch skidders with external sensors coupled with digital photography and GPS technology.*

***Key words:*** *production studies, sensor, automation, pattern recognition.*

## 1. Introduction

Forest production studies are tools of great importance in forest engineering research and practice. They are seen as being crucial to promote innovation and maintain the competitive edge of forest industries [6], helping researchers to understand the behaviour of forest equipment as a response to its operational environment [9] while their results have a wide range of applicability in designing effective forest based product systems. Forest practitioners use the results of forest production studies in planning, organizing and implementing various forestry related activities. While the main goal of the forest work production studies remained the same, their focus has shifted to system optimization by wider scopes even if such studies are still using basic techniques and there is a strong belief that manual studies

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will be used also in the future [6].

Nevertheless, carrying on forest work studies in a traditional fashion involves the allocation of significant resources including, but not limited to highly trained personnel, time and financial capital. Substantial trained human resources are needed to collect the field data as described, for instance, in [4] but also for processing the data at the office, an activity that could be very intensive in terms of time and computational effort [7]. On the other hand, field data collection in a traditional fashion involves the presence of researchers near the forest workers and hazardous equipment, a fact that may cause at least three foreseeable problems [1]: produces changes in work behaviour, may impair the safety of researchers and may cause delays induced by the study itself. The research personnel involved in data collection activities should be able to undertake the rigors of open sky work, that may involve the work being carried on in extremely low or high air temperatures, presence of snow layer, steep terrain and substantial distances to be covered by walking. The amount of needed financial resources depends to a great extent on the number of persons involved in data collection activities. However, recent research shows that most of the financial resources supporting the forestry-related work studies are coming from national-level budgets [6]. This often results in low or no financing at all otherwise important applied research initiatives able to produce indispensable data that supports the competitiveness of forest industry, leading to rather few studies [3] unable to cover the variability of forestry operations in specific regions [5].

One way to overcome the lack of resources is aiming at least to approach the field data collection by automating such tasks. The automation of field data collection would mean to design methods and to use artificial capabilities (instruments, devices, procedures etc.) able to substitute the specific human capability (intelligence, perception and effort) and yet to be able to produce data at similar quantitative and qualitative specifications as any trained field researcher would do. In traditional approaches, the human physical effort related to data collection is that of measuring values of some variables considered as being relevant for the study, as well as that related to data registering in analogic or digital formats. At the same time, human intelligence is used to logically separate certain observed tasks that are considered as being important for the study. In this direction, humans use their sensorial system to evaluate specific instances of their surrounding (observed) environment. While the sensorial (perceptive) capability of humans may be substituted to a significant extent by using surrogates such as the artificially created sensors, which also may help in accurately estimating values of some variables of interest, the human intelligence is rather difficult to replace.

Many of the state-of-art timber harvesting equipment make use of purposely designed sensors to manage the operations and to collect meaningful data about its performance. It is the case of actual harvesters and forwarders, some of the cable yarders, as well as some of the skidders used in timber harvesting operations. Nevertheless, in many parts of the world, there are still used otherwise old machines that are not equipped with such capabilities making it impossible to automatically collect data of interest. For instance, cable skidders are still one of the preferred options when dealing with timber extraction [2]. Such forest machines may lack a sensor system able to monitor those of their specific functions that are important for forestry work studies due to several reasons including their manufacturing concept at the time they were built, increments of purchasing costs by integrating more technology which otherwise could be of no interest for their presumptive owners, or the limited technical capability to place sensors on.

Meanwhile, the sensor development technology progressed at a significant pace. Nowadays, sensors able to measure and record data on physical phenomena such as movement detection, vibration, sound pressure level, light detection and ranging as well as the already well-spread GPS technology are available at consumer-grade competitive purchasing costs.

This paper aims at describe a methodological concept for turning a regular winch skidder into a machine able to collect the data needed in forest work studies by integrating a high degree of autonomy in such tasks. In order to do that, there are discussed the typical operational functions of a winch skidder followed by the typical data needed to be collected in forest work studies as well as the data specific to winch skidders. Then a concept of automating data collection is presented in detail with some examples available from previous tests or studies carried out in Romania.

## 2. Typical Functions of a Winch Skidder

A winch skidder is a forestry machine built to undertake (perform) a set of operational functions that enable the (i) concentration of otherwise dispersed logs in the rear part of the machine by winching and (ii) extraction of logs to the roadside [2]. Logs' concentration is carried out both by using manual and mechanical means. Manual tasks involve the cable pulling to the log, log hooking and, when needed, log unhooking in the rear part of machine [8]. This group of tasks is done without mechanical assistance. The effective winching is carried out mechanically by winding the cables on drums. Hoisting functions are enabled in a similar manner by hooking the loads to be extracted and raising their ends using the cables. At the roadside, the cables are released, loads are manually detached and the machine is enabled to carry on other functions such as piling the logs or returning to the winching site.

## 3. Typical Data Collected in Forest Production Studies

Forest production studies cover the sampling of complex data and wide data ranges. Outputs in terms of production need to be estimated in order to derive productive performance indicators such as the productivity and (or) efficiency [1]. Production can be estimated or measured by counting the number of logs and (or) by estimating the extracted volume or mass. The extracted volume per turn is estimated based on dimensional characteristics of logs while the mass is a function of volume. Time inputs are also needed in order to derive the productive performance indicators. Here, the aim may be to breakdown the time inputs at elemental level and to separate different kind of delays from the productive time. This helps in the estimation of gross and net production rates, as well as in understanding the functional behaviour in relation to selected operational variables [1]. The measurement of process variables is particularly important in different kind of forest production studies. While a selection on logical criteria [1] helps identifying those variables that have the potential to affect the variation of inputs and outputs of the studied system, in the case of winching and skidding operations, at least winching and on-trail skidding distances are required. The energy inputs are typically measured as consumption of fuel and lubricants. Coupled with typical production data such as the extracted volume, the results of energetic measurements help in the assessment of environmental performance of a given system [10].

## 4. A Concept to Automatically Collect Production Data for Winch Skidders

As mentioned, the output of skidding operations in terms of production is frequently estimated as the number of skidded logs and the volume skidded per turn. It can be measured either at the winching place or at the landing site. The first option involves the research work being carried out in a hazardous place, near tensioned cables, probably in steep terrain, and it may interfere with the usual way of doing the work resulting in delays caused by the study itself. The second option is more suitable due to the fact that measurements may be carried out in less hazardous and accessible places, making it easier to get the logs' dimensions and to compute the extracted volume.

While the cut-to-length technology enables data collection on the production outputs by specific systems that use sensors, in the case of winch skidders it is rather difficult to integrate such a technology, given their construction. However, this situation can be bridged using the latest technologies such as the digital photography coupled with GPS (Geographic Positioning System) and traditional measurements carried out at landing if needed. In particular, the winching operations are to be developed mainly on the rear part of skidder's longitudinal axis, a fact that allows the mounting of a digital camera on the cab. The camera should be set up in order to get photographs based on a time interval constraint (Figure 1). An example may be that of using a GOPRO ® professional camera that supports functions such as taking photos in wide view mode at time intervals that can be predefined. This approach would enable the collection of time-stamped photographic instances that should enable the estimation of the number of winched logs. In addition, the time data is encoded in EXIF files enabling the pairing of photographs with GPS tracklogs following a time synchronization between the two devices - the digital camera and a GPS unit - and the setup of the same time sampling interval on both devices. Another option would be that of using GPS units able to collect geotagged photographs with the condition to allow setups for given time sampling intervals. Data from internal storages can be imported in specific software that enables geotagging of photographs using the coordinates collected by the GPS unit. Examples of free software having such capabilities are the Base Camp ® of Garmin ® and Google Earth ® of Google ®. Then, estimates of production in terms of extracted cubic meters can be produced turn-wise at the roadside by a single researcher.

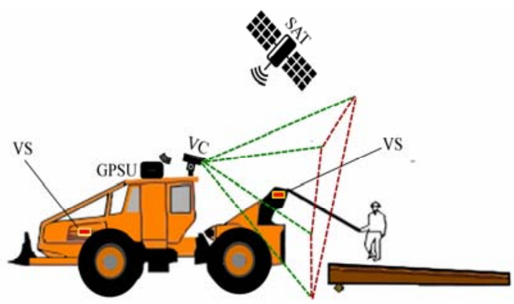


Fig. 1. *A concept of equipping a winch skidder with external sensors able to automatically collect production data: SAT - satellite, GPSU - GPS unit, VC - digital video camera, VS - vibration (motion detection) sensor*

The collected photographic data should enable also the supervision of the work being carried out with both drums of the winch, as well as the monitoring of more than one cable or choker setter. GPS and photographic time data may be further used to derive the data sets needed in a time study, including the operational distances for the on-trail skidding. The proportion of mechanical use of the winch could be also inferred from such data. However, there is a limited room for deriving the winching distance using this approach. An option in this direction may include the implementation of a visually signalling system using visible yet resilient tags on the cables. Another option would be that of equipping the free cable extremities with mini-GPS receivers that should be capable to undertake external forces caused by the working environment.

Monitoring the mechanical use of winch as well as the manual use of cables are equally important in deriving the time spent in different work elements, with applications in time studies carried out at elemental level. The same applies to the skidder's engine running time. While GPS data can be very useful in predicting the engine running time during those work elements involving movement on skid trails (empty and loaded turns), it cannot be used to predict the engine running time when the machine is stopped at the winching area. Moreover, at the winching place, the engine running may or may not overlap with the mechanical use of winches. Nevertheless, this kind of data could be gathered using sensors of motion detection, sound pressure and vibration. In particular, motion detection and vibration sensors are designed to capture the vibration acceleration and they proved to be very useful in those tasks aiming to monitor the behaviour of mechanical assemblies and devices. A specific property that can be used to differentiate between operational functions or functioning regimes is that related to vibration acceleration which yields different patterns on specific axes. This could help the researcher to discriminate a given work element as a function of magnitude in the vibration's acceleration on a specific axis or by combining the readings on 2 or 3 axes. An example of data gathered using a vibration sensor is given in Figure 2 for a typical chainsaw. A correct separation of the time spent in performing different skidding functions would be a matter of placing such sensors in the right places on the skidder. Obviously, in the case of winches equipped with two drums, units should be used on each drum to be able to collect separate data for each of them. Then, a third unit should be placed in a suitable place near the skidder's engine, enabling this way the collection of data related to the engine's functioning regime. While there are many types of motion detection and vibration sensors, some of them have built-in capabilities and functionalities that enable their synchronization with the time provided by a computer used to set up and download the data. As such, data from units placed at different locations on a skidder may be used in a common desk analysis. In addition, synchronization should be done also with the camera and GPS unit(s) time, a fact that should allow the comparison and common analysis of data yielded by all the used sensors.

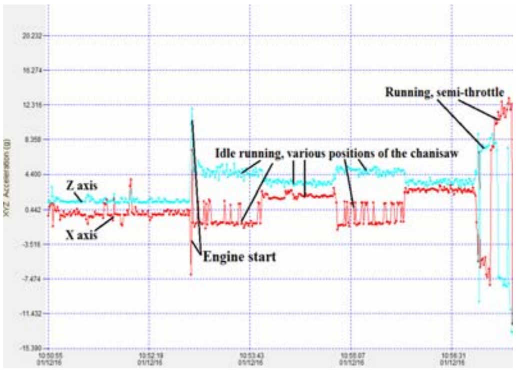


Fig. 2. *Patterns recorded by a vibration sensor for different regimes of engine functioning in the case of a chainsaw*

Sound pressure sensors are able to detect changes of sound intensity and they have proved to be very useful in ergonomic assessments of forest work. Nevertheless, the change of sound pressure level is also a property that can be used to discriminate between different regimes in terms of engine functioning. As such, sound pressure levels characteristic to a stopped engine, idling engine or an engine running at full capacity may be captured as a function of the time spent by a machine in such regimes. While possible applications may be those of monitoring the engine's behaviour during the operations, their use to collect data related to winch utilization may be limited due to possible interferences with the sound produced by machine's engine.

A common problem in using motion detection, sound pressure and vibration sensors is that of actually getting an accurate separation of the time elements from the collected data pools. Knowing that the vibration acceleration or the magnitude of sound pressure level could be affected by the state of a mechanical device taken into study, it is obvious that different machines or mechanical devices would yield different magnitudes for given functioning regimes, a fact that advocates for carrying out separate (comparative) studies aiming to get the data needed to build computer aided algorithms able to accurately separate work elements based on specific predefined thresholds. Such an approach would implement techniques specific to training a computer algorithm (eventually by trial and error) to learn and differentiate between patterns (pattern recognition) based on known truth (comparable data) giving the possibility to use the best matching thresholds in order to interpret the field collected data pools at their extent. By joint analysis of data provided by all the sensors, delays could be identified and separated from productive time. Also, depending on the specific capabilities (i.e. battery life) the use of a sensor system such as that described herein could solve the problem of long-term data collection.

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