SIMULCABLE, a new software to optimise the line implantation for cable yarding

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Abstract:
In mountain areas, some foresters use cable yarders in logging operations. The necessary preliminary study for the line implantation can only be made by a few specialists and requires a lot of time. Many logging site parameters have to be taken into account: topography, positions of the pylons and their numbers, maximum tension of the line… All theses parameters are crucial for the cost of the line installation.
SIMULCABLE uses input data on the topographic profile that may come from different sources, such as digital elevation models, paper maps, or in-situ measurements.
With the position of the cable yarder, the terminal pylon and the parameters of the cable, the software calculates the tensions in the cable in charge.
The output of SIMULCABLE is a visualisation in 2D or 3D, showing the position of the cable yarder and the skyline in charge. Moving a pylon when the cable is close to or on the ground generates a new simulation. The result of the calculations (tensions in the cable) also provides information about the pylons and anchors. The user can easily simulate several positions of the pylons in order to choose the best solution and determine the number of necessary pylons and their proper position.

Keywords: cable yarding, line implantation, strength, software

1 Introduction

Cable yarding is used in logging situations when traditional ground-based extraction methods (with a forwarder or a cable skidder) cannot be used, because of access difficulties, such as swamp areas, river crossings, or steep mountains where building a road is either too expensive or not compatible with nature protection goals. It is nonetheless more costly than traditional logging.

In France, logging operations by cable yarder are rarely used. Less than fifteen enterprises are equipped with cable cranes, and 3 others with long cable in the Alps. The trend is to develop the cable crane, which is quickly installed and used in different configurations: uphill, downhill or in flat terrain. Each year, some enterprises of neighbouring countries (Italy, Czech Republic, and Switzerland) come to France for logging operations with cable cranes.

For all these enterprises, determining the logging's price is a complex process: it depends on the expected productivity, but also on the line implantation and the number of supports/pylons (natural or artificial) which must be erected. It can take from 3 hours to 2 or 3 days to install one line. This has a big impact on the global productivity and the cost of the operation.

Therefore, in order to help logging enterprises to make the best choice for their line implantation, FCBA (French forest and wood technical institute) and ONF (the French organisation in charge of the management of public forests) have developed specific software: SIMULCABLE. This paper describes some basics about cable yarding and how SIMULCABLE can provide support to logging contractors, wood supplying companies and forest managers to properly install the skyline and provide appropriate information which will facilitate the estimation *a priori* of the costs of such installation.

2 Logging with cable crane

In the past, cable yarding was used only in mountain areas, with long cable (2 km). This setup required a heavy winch at the top of the line (carried by helicopter), and a minimum of 3 persons for the installation and production.

Over the past ten years, new technologies have appeared with cable cranes: a winch and a crane (8 to 15 meters high) with electronic assistance. The crane is built on a truck, or on a trailer (with its own motorisation or relying on the motor of a tractor). The trailer must be installed on a road. Some new equipment offers up to 1200 meters of cable and a six tons potential carriage, while the classic equipment on a trailer allows installing 700 to 800 meters of cable with a three tons carrier.

2.1 The used conditions

The advantage of cable crane is the quick installation and the possibility of logging in various situations: uphill or downhill the road. Whole trees can be extracted, with top and branches, which will be cut at roadside by a processor or a harvester. Production of wood chips from slash, for the energy market, is then easier. Last, logging operators can work in relatively safe conditions, and a high productivity is possible.

The skyline is installed on the top of the crane and on a tree (terminal natural pylon) at the end of the logging site. This terminal pylon must be selected and identified before the beginning of the logging operation. Some other trees must also stay around the crane and terminal pylon, in order to install anchors for the line stability.

Below the skyline all the trees must be cut, except potential intermediate pylons that may be needed according to the topographic profile: the skyline in charge must never touch the ground.

The felling is generally done 40 meters on both sides of the line. 500 meters of line can then cover a thinning surface area of 4 hectares.

2.2 The players of logging

In France, 3 main actors are concerned by the organisation of logging operations: the forest owner, the logging contractor and the wood supplying company.

- The forest owner: most of the time, in France, the forests in mountains areas are public forests (belonging to the State or public district). There, the forest management is ensured by the ONF. In private forest, the management is performed by experts or cooperatives. Usually the forest owner delegates such forest managers to take care of the selling of standing trees to supplying companies, or to organize and supervise the logging operation if he prefers to sell logs at road side. In this last case, forest managers have to assess the logging costs to establish a business plan of the cutting, but also to choose and contract with the logging contractor.
- The logging contractor: he provides logging services and usually charges its work according to the volume of wood to be harvested. He must plan its productivity on the specific logging site and set the price as a consequence. The line installation and especially the number of pylons to set up have a big impact on the system's productivity.
- The wood supplying company: the purchase can be either of standing trees or stems at the roadside. The wood supplying company is concerned by the logging only when he buys standing trees: he has to organize the logging operation and contract with a logging contractor, the same way the forest owner does when he sell logs at the roadside.

All these actors don't need the same information and precisions on the logging site.

2.3 Expertise requirements

The cable crane logging system is very a complex and technical operation. A variety of technical capacities are required: mechanics, use of chainsaw and wood lifting machines, techniques for climbing in trees. However, the preliminary step for installing the line is even more complex: localisation of the trailer implantation and of the terminal tree as well as of the respective anchors. Indeed, the felling of the trees is done after the identification of the line. This localisation is generally done with a compass or, sometimes, using a GPS, without real visibility of the global topographic profile and a clear view on the needed number of intermediate pylons. After the line installation, it becomes difficult to add more supports if all the trees are cut. Therefore, operators generally leave some trees instinctively, in case additional supports should be needed. The knowledge of the profile and the identification of the needed number of pylons is a real support for the line implantation.

3 Simulcable software

The principle of this software is to calculate tensions in the skyline and in the anchors when the cable is in charge. The 2D or 3D visualisation shows the places where the cable is too close of the ground, and the operator can then add a support at the right place.

The first version of Simulcable only covers the situation of a “fixed skyline”, when the suspension cable is fixed between the crane and a tree. The next version will include a “running skyline” module. This other technique for logging, where the skyline moves with the carrier, is not yet used in France.

The software is a standalone application. The operator just needs a computer without a web connexion.

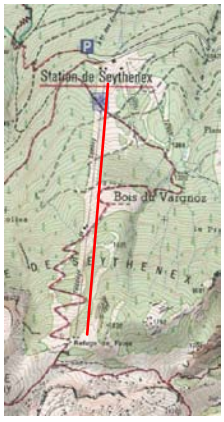
3.1 Parameters

Topographic profiles

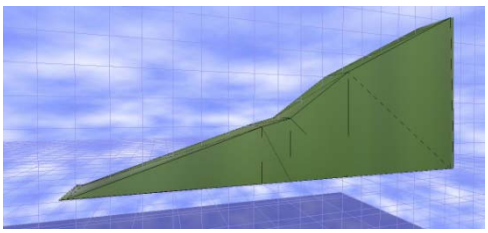
The operator needs to know where the cable crane and the terminal support will be installed on the logging site. Then, input data needed to describe the topographic profile can be obtained from a variety of sources:

- Digital elevation models: the precision (1m) is very interesting and helpful, but is rarely used in France because of its high price,
- Paper maps (generally 1/25000): by this way, the operators can have an overview of the line. However, the precision of these data, and especially in mountains, requires an in-situ validation (table 1), otherwise the 10 meters height precision of the map may invalidate the calculated line implantation ,
- Raise of ground: the operator has to cross the course of the line with compass and topofil, to get a real profile with sufficient precision.

Table 1: profile data obtained from map and resulting profile on SIMULCABLE



Point	Distance on the	Altitude (m)	Difference in height
0	0	1250	
1	24	1450	200
2	28.5	1480	30
3	38.5	1560	180
4	60.5	1830	270



Cable yarder parameters

The parameters of the cable are also used as input data. The software makes different suggestions for the cable yarder parameters' values, but the operator can set and save his own data:

- diameter (mm) of the cable for the skyline and the main line. The weight per meter is set by default by the software, but if the operator decides to set the diameter of his own cable, he has to provide this value and save it as corresponding to his own cable. The rupture resistance (strength) also has to be provided,
- the carriage: its weight and the maximum weight it can carry;
- safety factor: minus 1, in general use 2 by default or 3. For example, if the safety factor is 2, the maximum tension in the cable is half the rupture resistance. This data is used for the calculation of the forces in cables,
- height of pylons: the operator can select in a menu a pylon having a given height, but can also modify this height according to his own equipment and installation.

3.2 Results

The mathematic equations have been made by the mechanical laboratory SERAM of the school ENSAM Cluny (France), and are enclosed.

The skyline

The first calculation will show the simulation (figure 1) of the skyline implantation in charge, and the points where the skyline could touch the ground level.

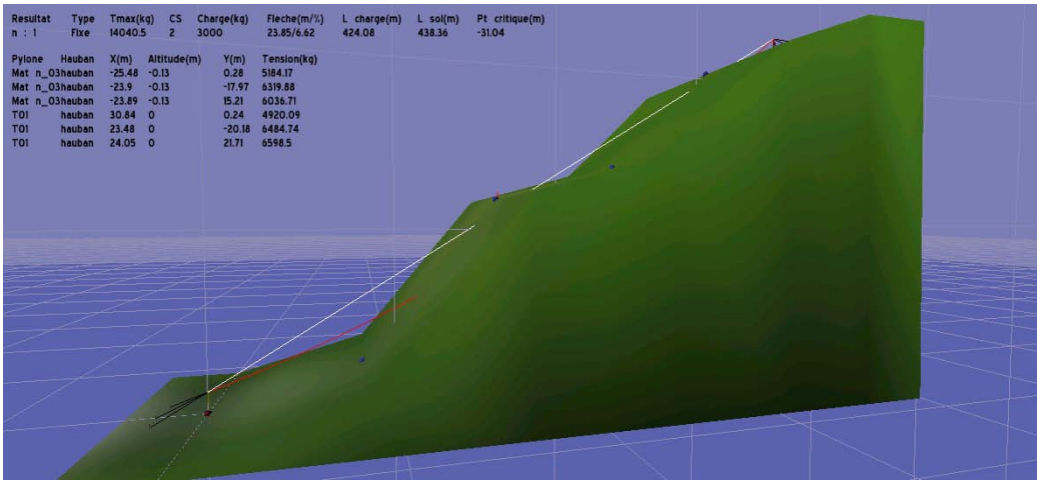


Figure 1: first visualisation (3D) after calculations

Therefore, the operators have to add pylons at the right point (top of profile curve), and make new simulations, until the skyline will be useful and at minimum 3 or 4 meters above the ground all along the profile (figure 2).

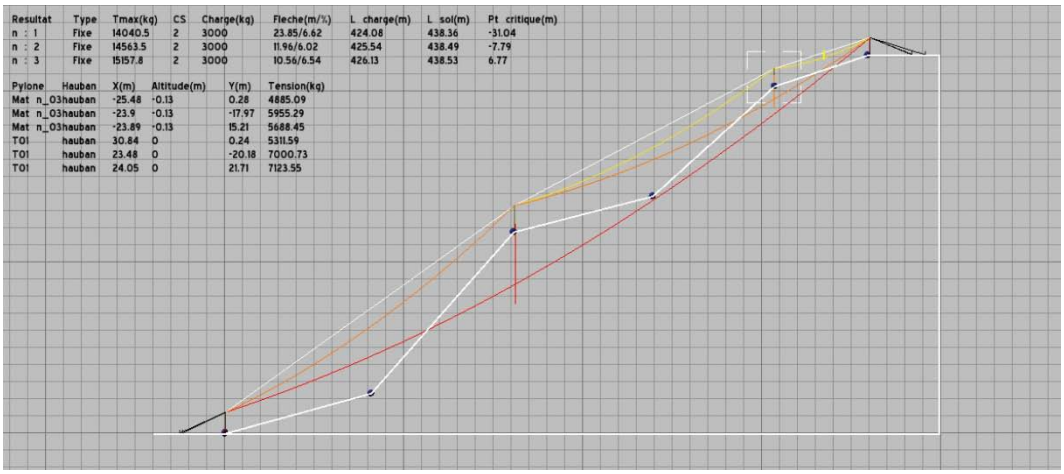


Figure 2: Final visualisation (2D), after adding 2 pylons

The results (table 2) of theses calculations determine the tensions in the skyline, the highest point of the line above the ground, as well as the lowest point and the length of the line. If the highest point is more than 40 m above the ground, this will be flagged to the operator, who has to declare such fact to the French civil aviation (French law).

Table 2: results of tensions in the skyline

Resultat	Type(m)	Tmax(kg)	CS(m)	Charge(kg)	Fleche(m/%)	L charge(m)	L sol(m)	Pt critique(m)	Pt haut(m)
n : 1	Fixe	14040.5	2	3000	23.85/6.62	424.08	438.36	-31.04	21.03
n : 2	Fixe	14563.5	2	3000	11.96/6.02	425.54	438.49	-7.79	38.64
n : 3	Fixe	15157.8	2	3000	10.56/6.54	426.13	438.53	6.77	38.64

These data are very useful for the cable operator before the line implantations, as they provide information on how many pylons to preserve or install (artificial support), and their proper position.

The anchors

In the software, the operator has the possibility of positioning the anchors of the crane and the terminal pylon.

With the calculations (table 3), the cable operator knows the tensions in each anchor maintaining a pylon and determines if his cable crane and anchors are sufficiently resistant (diameter of the anchors, power of the winch). If necessary, he can modify the anchors' implantation or their number.

Table 3: results of tensions in the anchors

Pylone	Hauban	X(m)	Altitude(m)	Y(m)	Tension(kg)
Mat n°03	hauban	-25.48	-0.13	0.28	4885.09
Mat n°03	hauban	-23.9	-0.13	-17.97	5955.29
Mat n°03	hauban	-23.89	-0.13	15.21	5688.45
T01	hauban	30.84	0	0.24	5311.59
T01	hauban	23.48	0	-20.18	7000.73
T01	hauban	24.05	0	21.71	7123.55

Theses results are not essential for the line implantation and for the cost calculation. But it is helpful to ensure the safety of the installation, by specifying if the number and the localization of the anchors are appropriate (figure 3).

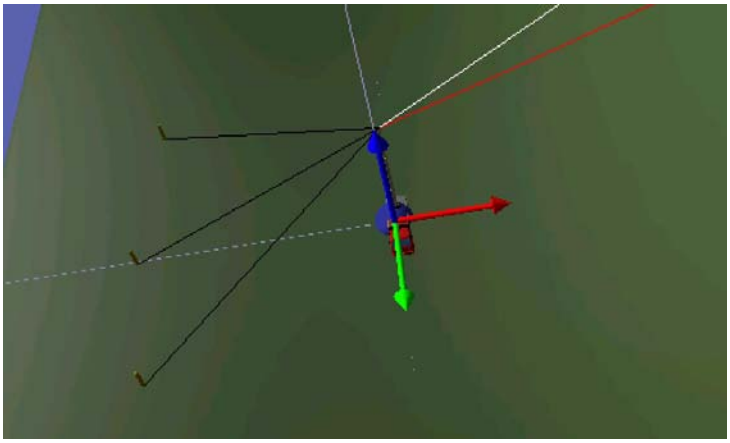


Figure 3: visualisation of the anchors

4 Conclusion and perspectives

In mountains areas, the Simulcable software is now very helpful for cable yarding contractors as it provides exactly the number of necessary pylons and their appropriate position. With this information, the operator can plan the time for the line installation as well as its cost. He can also be ensured that the line can be operated according to safety guidelines in terms of maximum tension.

For the forest manager, the use is different: the map of the line implantation is used for the planning of the logging operation.

The current version of Simulcable is only a first module for cable yarding planning. In the future it can be extended. Different links could be implemented with current or future forest research projects:

- digital elevation models and Lidar technologies will offer the possibility to localise each tree, together with information on its species, its volume and its quality. Then, it will be possible to simulate different thinning areas, and calculate the corresponding volume which can be harvested;
- optimisation of cable line position to be as near as possible to the intended felling detected by digital elevation model. With a logged area of 40 meters on either sides of the line, the skyline will be installed where the intended logged volume will be optimal (in terms of quantity and quality). The “yield index" which represents the ratio between the extracted volume and the total length of the line (m^3/linear meter) will be better, and hopefully bring a cost decrease;

- adaptation to a software for the cost calculation, like Hepromo developed by the WSL (Switzerland).

With all theses different modules, in the future, it will be easier to identify exactly the logging places for cable yarding, the required equipment for the forest harvesting, and the cost of wood extraction.

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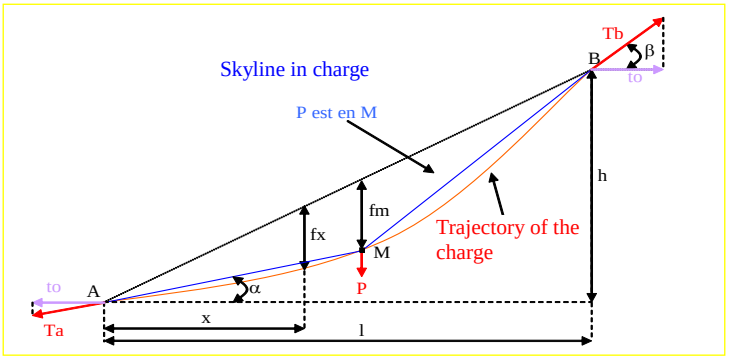
6 Appendix

Calculation of the forces in the skyline

The forces in the skyline and anchors are calculated with the cable in charge, and give maximum tensions. Every point of the skyline is treated according to the calculations reported on the following figure (figure 4). In the results, every point is represented on a curve which restores the exact position of the skyline.



q1 : linear weight of skyline

q2 : linear weight of the main line

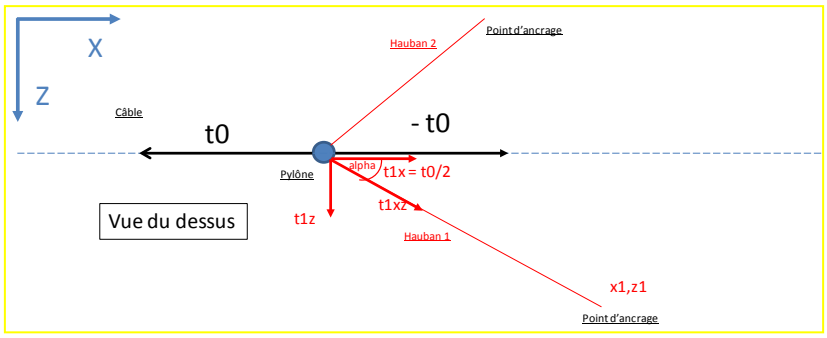
$$fx = \frac{x \,.\, (l-x).[\, l/2 \,.\, (q1+q2) + P]}{l \,.\, to}$$

$$\beta = \mathrm{Arctan}(-l/h) + \mathrm{Arccos}\left[\frac{l/2 \,.\, [\, l/2.(q1+q2) + P\,]}{((l.Tb)^2 + (h.Tb)^2)^{1/2}}\right]$$

Figure 4: view of the line in charge

Calculation of the forces in anchors

Anchors must be as symmetric as possible to obtain a good distribution of the tensions. The calculation for the anchors is not necessary for the line implantation. To have the results, the operator has to know exactly (position of the pylon in 3 dimensions) where the anchors will be installed around the cable crane and the terminal support. The calculation arises from figure 5 and 6.

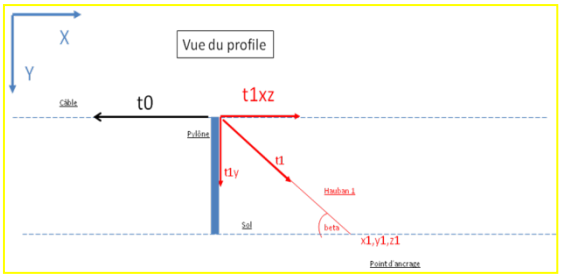


$t1z = t1x * Tan(alpha)$

$t1xz = sqrt(t1x^2 + t1z^2)$

max alpha = 80°

Figure 5: Top view of the anchors



$t1y = t1xz * Tan(beta)$

$t1 = sqrt(t1xz^2 + t1y^2)$

Figure 6: Profile view of anchors

Calculations realized by the mechanical laboratory SERAM of the school ENSAM Cluny (France)