FORESTRY IN 2020
OPERATING THE HARVESTER CRANE

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ABSTRACT

An interaction for man and machine in a future semi-automated world.

The history of forest industry goes long back in time in Sweden, as it is a cornerstone of the Swedish economy. In the past, there used to be extreme physical workload as most of the tasks were done by hands and tools. Whereas today these tasks are being replaced with heavy forestry machinery that requires a high mental workload.

Operating these complex forestry machinery brings new complications with itself. It takes many years to prepare new operators to be ready for such complex machine. And operating the forestry machine for a longer period of time will intensively exhaust the mind of the operator.

This project introduces a new user interface for forestry machines that takes place in a near future setting. We explored the best qualities of operators and automated machinery and are proposing a semi-automated scenario which tackles the problem on two different interaction levels: an augmented GUI that gives the operator an overview on his tasks and a futuristic controller that invites the operator to initiate automated actions.

We believe offering these semi-automated machinery will help the operator to lower his mental workload. In the end, it’s not the new UI that makes this project so valuable. We envisioned the future work state of the operators in a way it could enhance the operators’ lives.

This project has been executed together with Umeå Institute of Design, SLU and Skogtekniska Klustret.
Combining the best of human operators and automated actions.
DESIGN PROCESS

Human-centered design for forestry context.

The project started with two field trips to Komatsu. The first trip was to get introduced to the overall experience in the forestry branch. In the second trip we were able to reach a deep understanding of the user’s need and the work environment. These insights became the fundamental user-centered basis on which we build upon during the rest of the project.

Throughout the project, we worked close as a team to analyse, map and generate new ideas. In order to further validate our thoughts we used hands-on design methods such as: bodystorming, role-playing, mock-ups and experience-prototyping. Using these methods helped us to create and feel the new experience. By also organizing external workshops and expert meetings, we were able to reflect and move forward in the design process.

Two key events that played an important role in our design process were the visits to the school of Forestry in Burträsk. These valuable visits gave us the opportunity to validate our new scenarios we created around our concepts. During our first visit we clarified important questions and assumptions we had about the user and their needs. During the second visit, we validated our story by showing the students and the teacher our concept and prototype. These new insights helped us to come up with our final concept as it is presented in this report.

1. Process video during midterm(https://www.youtube.com/watch?v=5GPFz8IdVas)

2. As a group, we performed bodystorming sessions to ideate on the experience and scenario.
LITERATURE RESEARCH

Our key quotes from the papers on forest industry and robotics.

Westerberg, S (2014)

“control of the on-board hydraulic boom crane is currently performed through continuous manual operation. This complicates the introduction of further incremental productivity improvements to the machines, as the operator becomes a bottleneck in the process. A suggested solution strategy is to enhance the production capacity by increasing the level of automation”

“Compared to conventional robots, such as the industrial robots commonly utilized for e.g. manufacturing, processing, or packaging tasks, the development rate of automated forestry robotic vehicles is much lower”

“Semi automated functions can reduce this gap between fast machines and slow operators”

Westerberg, S., Shiriaev, A. (2013)

“users considered the semi-automated tasks to reduce the cognitive workload and to allow the user to change focus from low-level crane control to other functions, such as more high-level task planning.”


“It is generally agreed that a synergy of human and robotic skills offers an opportunity to enhance the capabilities of today’s robotic systems, while also increasing their robustness and reliability”
The team made two visits to the high schools of forestry in Burträsk outside Skellefteå. The school was specialized in teaching students how to operate and maintain forest machines. It was a great opportunity to meet young people learning how to operate forest machines. Interviews were performed with four students. We also interviewed one of the teachers at the school who himself had a background as a forest machine operator. As a teacher he had great knowledge about the learning process of operating forest machines. At the same time he could reflect on how it was to be an experienced operator.

He told us that young people who are learning to operate the machines use the controls like other electronic controls they are used to, such as game controllers. The students had a tendency to push the joystick quickly and often when maneuvering the crane.

Further he explains that the joysticks in today’s machines are fully electronic and fairly small, but they are not supposed to be used Nintendo-style. Instead, they require smooth continuous input like a soft hydraulic systems. He meant that this was an example of how the manufacturers of the machines had adapted the controls to better fit the driving style of experienced operators instead of young future operators. The controls in today’s machines wasn’t intuitive for young operators. The industry

switched to electronic controls a long time ago, but the next generation machines had always been designed to fit the style of the older operators.

Another problem with the joysticks was that they did not offer any of the haptic feedback like the old hydraulic system used to do. Instead of feeling what was going on in the crane, the operators now had to rely on visual cues. He meant that the joysticks used today was a compromise between the old and the new, without having the best of the two.

The students (four) were interviewed using a semi-structured interview and a sorting task. All of them were last year student graduating in one semester. Most questions asked were about how it was to be a student learning to operate the machines, what they liked, didn’t like and what was the hardest to learn.

Most of them had similar ideas about the main aspects of the job. They all agreed that it is really fun to operate big machines, weighing several tons, cutting down trees like they were mowing grass, and that it was a hassle fixing the machines when they broke down. However, the most important insight they shared was that, using today’s controls, it was hard to keep up the speed and do high-level planning at the time. During the sorting
OBSERVATIONS & INTERVIEWS

Burträsk School of Forestry. Second visit.
Focused on making important decisions.

task they ranked mental workload, fun and learning as the most important aspects of a good forest machine design.

They said, if the planning is not done well, the quality of the work goes down and money is lost. If too much time is spent on planning instead of cutting trees, the production volume gets too low.

According to the interviewees, this was what separated an experienced operator from a beginner. Being able to master the controls, make good decisions and plan ahead at the same time was something that would take them several years to learn.

At the second visit we performed a new round of interviews with the student. At this time our work had moved into the concept phase and testing phase. The student were presented with our findings and main ideas for the control of the future. This was followed by a discussion and a short ideation session.

Two of the student agreed fully that a self-moving/motion assisted joysticks would increase the quality of their work. They thought it would enable them to spend more time on planning and making good decisions rather than focusing on controlling every single movement of the crane. The other two were more skeptical and kept asking how this would be implemented, from a technical point of view. They liked it on a hypothetical plane but thought it was too futuristic for the year 2020.

An interesting observation was that the two sceptical student were the biggest fans of the automatic features available in the schools new harvester. The automatic sequence system that cut and debranched the tree was there favorite. The optimistic students envisioned a highly automated system where the operator focused on making important decisions and high-level planning.
The first interviews were conducted with machine operators Bernt Hermansson and Lars-Anders Nilsson at the forestry company NH-skog. At the day of the interview we started by eating lunch together and performing a semi-structured interview. Lars-Anders and Bernt drove one type of forest machine each, a forwarder and a harvester. They usually didn’t switch machines. After lunch we rode along in the machines for the remaining part of their work day to shoot video, make observations and continuing the interviews.

As an experienced operator, Lars-Anders was so fast using the harvester controls that he had a hard time explaining all the control inputs in real time. Most times he used up to four different commands at the same time. When asked how hard this was to do, he answered that it was not, since he had done it for over 40 years, but that he still had to remain fully focused at all times.

Even after 40 years Lars-Anders had to remind himself not to work too fast so he could stay focused all day. He explained that if you push yourself hard you can produce more, but only for a short while. It was important to find a good balance. Younger drivers often have a hard time finding this balance, especially when they are hired by big companies that want to produce as much as possible.
Doing task analysis gave us the chance to see the workflow of the Harvester operator clearly. The main three tasks for the operators are Planning, Felling and Processing. We further defined the substeps for the main tasks and mapped their activities underneath. It was easy to see which activities were repetitive during operation. Two repetitive actions are “selecting a tree” and “slicing the logs”.

During task analysis, we also made some technology assumptions on which actions will likely be done by the operator or the system in the forest of 2020. We called this as defining the “level of uncertainty”. Some activities that we assumed to be highly automated were:

- Navigate crane to tree.
- Grab tree.
- Rotate cabin to slicing area.
- Slice the logs.
- Leave the rest of the branch.

Continuing on the discussions for future ideas on task level, we agreed that operator should be able to do manual takeover at all times even during the automated actions.
FOCUS AREAS

Creating opportunity areas gave us a direction.

After we did the field research and interviews at the training center, we began pointing out interesting aspects that we would like the project to be about. By going through the research materials and digging the user quotes, we were able to filter the most important aspects. We decided on three focus areas for the project: Learn, Enhance and Focus. Each focus area has its unique set of questions that needed to be explored further. In respective to areas, they are:

Learn
- How can people with different skill levels still operate in a successful way?
- How can the actions of the machine be visible on the interface?
- What can “a good control panel” look like for the operator?

Enhance
- How can the operator feel connected to his actions?
- How can it be a fun experience for the operators?
- What would be the perfect feedback(s) for the operator?

Focus
- In what ways automation can improve his focus at work?
- How can an operator manage his actions in the best way?
- What would be the best work process for the operator?

1. Key questions related to each focus area have been put in an importance order.

2. Through group discussions, focus areas got narrower.
IDEATION

Searching for solutions that brings out the best of the operator.

Defining the focus areas helped us to start the ideation phase. We have performed two ideation sessions: first one was done internally by ourselves and second one was together with other students from the Master programmes. The aim for these ideation sessions was to create as many ideas as possible. It was fruitful to include other students in our ideation session which gave us further insights. The ideas that stood out are summarized below:

- **Alternative work order.** Changing the work process (e.g. selecting the pile area before deciding on the trees to cut)
- **Recording and assisting the movements.** Interface moves your hand physically to teach as a guiding movement.
- **Real time planing.** You are ahead of the vehicle. Alternative work order.
- **Providing dialogue between the operator & the machine.** More focus can be put on the actions Alternative work order.
- **Transparency.** Relevant positioning of information by context and location. Alternative work order.
- **Feeling where you are in the process.** Enhancing the operation by feedbacks.
- **Learning and understanding the user.** Every operator can have their own preferences.
- **Automate with augmented reality.** Mix physical controls with the visual clues.

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1. At the internal ideation session, we started with a blank paper and took turns to build upon each others’ ideas.

2. The second ideation session included product designers and we learnt from their experience with heavy machinery operations.
Today’s forest machines, in this case the harvester, require continuous manual input from the operator. The crane used for cutting and processing trees is operated by a large number of individually controlled actuators. To effectively control the harvester, the operator must be able to give up to six commands simultaneously. Apart from manual input, the operator is also required to make hundreds of decisions every minute to keep the up the quality of the work. High level planning such as overview thinking, ecological planning and team strategy is done on top of this. These reasons makes the forest harvester one of the most advanced industrial machines, in the world, from an operator perspective.

Historically, working in the forest was hard physical labour. Today, forest machines have become so reliable and fast that the main problem is to keep up mentally rather than physically. This has led the industry to research how automation can enable the operator to better utilize the full capacity of the machines.

Currently, new control systems are mainly developed for the skills and needs of experienced operators. This has made it difficult to implement changes that are aimed to toward young inexperienced operators. Operators that, already, are fully skilled might not benefit as much from automation as young operators. Experienced operators are therefore less motivated to spend time learning new control systems than beginners. This can make it difficult to implement technology.

However, the mechanical speed and endurance of today’s forest machines have increased to such an extent that the operators now are becoming the bottleneck. Faster machines might no longer improve overall production if the operators cannot keep up.

The main challenge for this course was to come up with a design for controlling the harvester crane that would improve the speed and quality for both beginners and experts.
PROTOTYPING  
Reflecting on the experience.

Throughout the project we created many prototypes at different stages in order to reflect on the experience. These prototypes varied from low paper mockups prototypes to more complex prototypes.

1. We re-created a physical version of the forwarder in order to experience the complexity of the current user interface. Experiencing these complexity helped us to reach a deeper understanding of the current problem.
2. We used pen, paper and wires in a bodystorm session to simply create the experience and feeling of manipulation and inviting the user to complete a certain task.
3. Another direction we went into was haptic vibration feedback. We created a control system that was able to control the crane head with hand gestures.
4. One of the first versions of boom-tip controller.
5. The high-fi model made it possible to map the semantics on a real controller. This opened up discussion for semantics and form.
6. We created a simple mechanical device with a push-coil which was able to push the controller in a certain direction. Using this mechanical device in a bodystorm helped us to iterate on different form. The current gearbox of automatisation is inspired by this prototype.
LAYERS OF INFORMATION

*Three layers that lower the mental workload.*

**TOP LAYER – AUGMENTED GRAPHICAL USER INTERFACE**
On the top layer, we designed an augmented GUI that gives the operator an overview. Augmentation benefits the operator as it makes the task easier by showing relevant information and informing the operator on the automated actions.

**MIDDLE LAYER – FUTURISTIC CONTROL UI**
In the middle layer, we designed a new controller that is able to invite the operator to initiate automated actions. Firstly, the controller works according to the BOOM-TIP principle. Secondly, it invites the operator to initiate the automated actions by lowering down the resistance. This controller is intuitive and easy-to-operate.

**BOTTOM LAYER – ENGAGING SENSES**
In the bottom layer, we focused on how to stimulate the senses when an automated action is offered. We designed the behavior of the controller to automatically get a grip on the tree when the crane head comes close to a tree. This is called the A.G.S. (Automatic Grip System). As the operator pushes the controller forward in order to grab a tree, the controller snaps when the A.G.S. activates itself. These haptic clues should help the operator to feel in control of the operation, and give him a clear understanding of the state-of-the-machine.

1. Our final concept is building on three aspects.
HEAD-UP DISPLAY

A visual augmentation that shows just enough what the operator needs.

Head-up display is designed to give the operator an overview on the operation without him needing to look at the controller. It starts in the beginning of the sequence by showing the nearby trees that are scanned. In our concept, this range is based on the distance which the cranehead is capable to move. Overall, the visual augmentation informs the operator on the automated actions and make the operator feel still in control.

The sequence of the visuals in respect to their order of appearance follows like below:

- **Showing trees.** Trees in range are pointed out. One tree can be suggested as ready for automation.
- **Grabbing a tree.** Suggested tree is grabbed. A visual that grows in time is shown during the grab.
- **Cut.** Cut is specified with a prominent orange color, different than rest of the operation. After confirming the automation cut, the cutting process is visualized with a rotating animation.
- **Define pile area.** When the tree is cut, augmentation asks whether the operator wants to take the tree to the left or to right.
- **Slice point.** Slice sizes are defined by the system and pointed out to operators by being highlighted.
- **Show pile area location.** The area where logs are going to be piled is shown to operator so that he doesn’t need to think in detail where exactly the pile is going to be at.

1. While cranehead is grabbing a tree, visual grows in time to indicate.

2. Pile area defined by the system and slicing points are highlighted.
The final design of the physical controller, the joystick, was based on key findings from the research and testing performed during the project. The main focus was the interaction, not the ergonomics or styling.

The concept joystick is about the same size as the standard komatsu model, but have little else in common. The key aspects of the new control is that the interaction is semantically related to the crane movements and actions. It’s a boom tip controller. Tilting it left/right, back/forth moves it across the XY-plane, moving the grip up/down moves it across the Z-plane.

The design also aimed to make it easy for the operator to go between automation and manual control. It enables the user to choose when to use automation depending on the task.

The design is based on one main scenario, the final cut. It has two automatic sequences that can be activated. These are: cut selected tree and process the tree to pile left/right. The automation is activated by moving the joystick into one of the openings that will appear when automation is available, like a manual gearbox. As long as the joystick is in the gear, the machine runs the sequence. If it’s moved back it goes to manual mode. If this is done before the sequence is completed it will stop.

The gears opens mechanically by a rotating ring that can be heard and felt in the joystick. Also, a magnet nudges the joystick when the cut-gear is opened, to provide further information about the state of the automation.

1. Final design of the joystick.
On the day of final presentation, we presented our concept with an explanatory video and had a live demo for our audience. The video shows how we addressed our concept for 2020 and lowered the mental workload with our proposed concept. The live demo helped us to get valuable feedback from the audience as they could completely feel the experience by interacting with the controller and seeing the graphics for the head-up display. We performed the live demo with our controller prototype that gave a nudge when an automated action is suggested to the operator and a processing sketch that included three trees to be selected in the view and displayed the key graphics for throughout the operation. Some of the valuable feedback we gathered that day are summarized below:

- **The concept really fits to the target group we are addressing to.** Beginner harvester operators would benefit from this concept as they would learn easier with this system.
- **The operator can feel where he is in the process.** With the haptic feedback, it’s very clear to be in control of the process and have the time to make your own decisions as an operator.
- **Not revealing the functions for all times is great.** The young operators would love to have only the necessary functions for each step of the operation and the gear in our concept does that.
- **The future look the concept carries for 2020 is believable.** Focusing on a specific context like “semiautomation in 2020” and envisioning the specific interaction was appreciated.

1. Our live demo included the controller prototype and the processing sketch on laptop

2. The final video illustrates the forestry of today and forestry of tomorrow with our design. ([https://www.youtube.com/watch?v=M_bWfrnLZhi](https://www.youtube.com/watch?v=M_bWfrnLZhi))