DESIGNING DIGITAL TOOLS TO SUPPORT HANDOFF AT SHIFT CHANGES IN AVALANCHE FORECASTING

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ABSTRACT: Avalanche forecasters typically work in teams, relying on the continuity of their shared understanding of avalanche conditions. Shift changes can disrupt this continuity as incoming forecasters need time to get up to speed with current conditions. While the conceptual model of avalanche hazard offers a structured way to describe existing conditions, it lacks important contextual information that informs hazard assessments. Without this context, forecasters can be left searching for clarifying information that could otherwise have been communicated. Handoff notes can provide this context but can be cumbersome to write because they require additional effort outside of the forecasters' core hazard assessment process.

Collaborative Visual Analytics offers practical methods to address handoff challenges by streamlining the process of collecting and organizing contextual information within existing analytic workflows, easing the burden of notetaking. While these methods have already demonstrated their value in domains like healthcare and investigative intelligence analysis, their effectiveness critically depends on them being appropriately integrated into a specific context of application. In collaboration with Avalanche Canada, we explore early design prototypes to understand how they might perform operationally and how to better tailor them to avalanche forecasting. Overall, forecasters thought our tools were easy to integrate into daily workflows and helpful for coordinating work. However, they also highlight specific challenges to be addressed. Drawing on lessons learned, we provide recommendations for successful implementation of such systems. This research highlights how dedicated digital handoff support tools could improve the efficiency and efficacy of team collaboration in avalanche forecasting.

KEYWORDS: Remote Forecasting, Shift Changes, Teamwork, Digital Support Tools

1. INTRODUCTION

Avalanche forecasting is an iterative process (e.g., LaChapelle, 1980; McClung, 2002) where new observations are continuously integrated into an existing mental model of the current conditions. This process starts with the first snowfall in the fall and continues until the snowpack has completely melted again. Since most avalanche safety operations consist of teams where forecasters take turns assessing conditions and making risk management decisions (Maguire and Percival, 2018), shift changes between forecasters can create disruptive discontinuities in the organizational mental model of the conditions (Nowak and Bartram, 2022; Nowak et al., 2020). Forecasters need time to fully understand current conditions, what has changed during their absence and why. While standards for hazard assessments like the Conceptual Model of Avalanche Hazard (Statham et al., 2018) have provided a common language for improved communication of the current state of the hazard, there remains a need for more contextual information to effectively handoff work during shift changes.

How observations and other contextual factors are used to determine specific avalanche hazard assessments is not well defined. Consequently, the choices involved in what avalanche problems to report and how to transition between them is a source of uncertainty and confusion (Hordowick, 2022; Klassen, 2013; Klassen et al., 2013). This is why hazard assessments alone provide only limited insight during shift changes, and forecasters coming on shift are typically left to review the prior day's observations to speculate about how assessment decisions were arrived at. (Nowak and Bartram, 2022). This disrupts continuity at shift changes and impacts the efficiency of the organization.

There are several existing practices to aid communication and ensure continuity in forecasting teams. These include daily meetings where any lapses of understanding can be addressed in discussions, the use of digital communication channels like email or various text chat tools, or snowpack structure monitoring tools like representative snowprofiles or lists of structural weak layers (Campbell et al, 2016). While these approaches do provide support for collaboration, the development of hand-off notes in particular is not well integrated into existing workflows. Consequently,

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they are often incomplete and left until the end of the day when it is much more difficult to recall specifics.

The objective of the present study is to build upon existing approaches for hand-off materials and explore strategies to better integrate them into existing workflows to make them more efficient and effective.

We draw on knowledge and methods from the domain of collaborative visual analytics (CVA) and explore how such methods may be tailored to the avalanche forecasting context. Such approaches have been effective in healthcare (Mueller et al., 2006) and intelligence analysis (Zhao et al., 2018) among numerous others. We report on a preliminary design study investigating novel approaches to create and communicate hand-off materials in practice during operational hazard assessment at Avalanche Canada. Our initial findings show promise in such approaches but also highlight specific challenges for future designs to address. Drawing on our preliminary experiences, we outline recommendations for tools to support handoff at shift changes in avalanche forecasting.

2. CHALLENGES OF HAND-OFF

The challenges of handoff in shift work are not unique to the avalanche world. Any field involving collaboration around analysis is reliant on the shared context of how evidence, findings, hypotheses, and knowledge relate to each other (Heer and Agrawala, 2008; Soares et al., 2016; Yusoff and Salim, 2015). Communication requires additional work beyond the task of analysis itself and therefore, collaborators communicate in ways that demand the least possible effort. Time constraints and complex situations involving contextual factors which are difficult to anticipate lead to shorthand notation instead of more explicit and standardized methods of reporting (Patterson, 2008). Hence, rigid standardization for handoff often fails, particularly in domains like healthcare which involve uncertainty, time constraints, and risk (Hilligoss and Moffatt-Bruce, 2014; Patterson, 2008; Patterson et al., 2004). Avalanche forecasting shares these characteristics.

Analysis and communication are generally treated as separate steps because articulating partial findings is difficult and disruptive to the work at hand (Sharma, 2008). At the same time, it is well-known in cognitive psychology that tasks such as analysis or reading lead to an understanding where specifics are forgotten but the essential meaning, the “gist”, is progressively developed and retained (Reyna, 2012; Elfenbein, 2018). This means that recalling relevant and detailed contextual information (e.g., specific evidence leading to assessment decisions) can be difficult while only communicating the gist is certain to be incomplete and ambiguous.

3. COLLABORATIVE VISUAL ANALYTICS

Visual analytics is a field defined as the “science of analytical reasoning facilitated by interactive visual interfaces” (Cook and Thomas, 2005). Collaborative visual analytics is a subdiscipline concerned with methods to better support collaborative analysis and provides several solutions to address the challenges of handoff during shift changes.

Integrating analysis and communication into one step can relieve some of the burden of communication and address the challenges of recalling specific information (Mathisen et al., 2019; Wood et al., 2019). This can be accomplished by capturing or pointing to contextual information while working. This strategy is sometimes referred to as “annotation” and is analogous to highlighting text while reading or writing notes in the margins of a book. It is much easier to recognize important information and highlight it to make it easier to find in the future than to recall it and articulate its significance after the fact. This strategy is a common solution for easing the burden of collaboration while at the same time capturing contextual information needed to develop a shared understanding among collaborators (Chung et al., 2010; Goyal et al., 2014; Mahyar and Tory, 2014; Shrinivasan and Van Wijk, 2009; Zhao et al., 2018).

However, such annotations can become unwieldy and cluttered. Just like it can be difficult to understand someone else’s messy notes and highlights in a textbook, it can be difficult for others to understand references to information in analytic tools without an understanding of their broader role and meaning. The solution to this is to use existing domain knowledge as a template to scaffold the organization of these annotations to make it easier for others to understand (Andrienko et al., 2018; Choi et al., 2019). For instance, this might involve using certain themes to categorize information, just like one might do when highlighting text in a textbook with different colors. Computers provide many more opportunities for presenting such information and making it easier to retrieve it when and where it is needed in the future. The use of the annotated information does not need to be limited to the original context where it was found but can be automatically referenced and retrieved in other displays, like those specifically designed to facilitate handoff.

4. METHODS

Our aim was to explore how and whether CVA solutions could be helpful in a public avalanche forecasting context. We were interested in testing how such approaches might be used in practice to better understand outstanding challenges and opportunities for tailoring such technologies to the public avalanche forecasting context.

Our study is grounded in theory and methods from design research. Instead of developing costly fully functional prototypes, we make use of cheap low-fidelity tools that mimic the functionality of a potential future but not yet developed tool to better understand their potential value (Lazar et al., 2017). Another integral aspect of design research is the continuous involvement of users. We solicited participation from four public avalanche forecasters at Avalanche Canada to think creatively about solutions that could be helpful. In addition, they used our prototypes during operational workdays to explore their effectiveness. This ensures that designs are informed by expert knowledge and practical experience that can only be gained by using a new technology in practice.

Our design explorations started with first asking three forecasters to record their screens during their workday and note information they thought would be important to carry forward to subsequent days and handoff to others. It was up to their discretion as to how to do this. Some vocalized their thoughts in the recordings while others took written notes. Forecasters were also asked to imagine ways that this information could be organized and presented to improve communication.

From this preliminary investigation, we identified two approaches for organizing contextual information to explore further: a) an expansion on the commonly used representative snowprofiles, and b) a system for tagging contextual information.

4.1 Expanded Representative Snowprofile

Representative snowprofiles showing the spatial and physical properties of the regional snowpack are common in mountain guiding operations and are used to capture the forecaster’s mental model of snowpack stratigraphy and summarize key aspects of the snowpack to focus on (Campbell et al, 2016).

We expanded this common tool to include further notes describing contextual information relevant to hazard assessment. To explore the functionality of this approach, one forecaster created a representative snowprofile annotated with the information they found important for handoff during an operational forecasting day, (Figure 1). Alongside each layer and the entire snowprofile diagram, the forecaster discussed relevant contextual information including references to evidence, recent weather, and their general interpretations and concerns about avalanche conditions. This snowprofile diagram was used in a real-world handoff with another forecaster who was instructed to begin their workday by reviewing this information. Both forecasters screen-recorded themselves during work and vocalized their thoughts in the recording. They were debriefed about this experience in an interview using remote video conferencing at a later point in time.

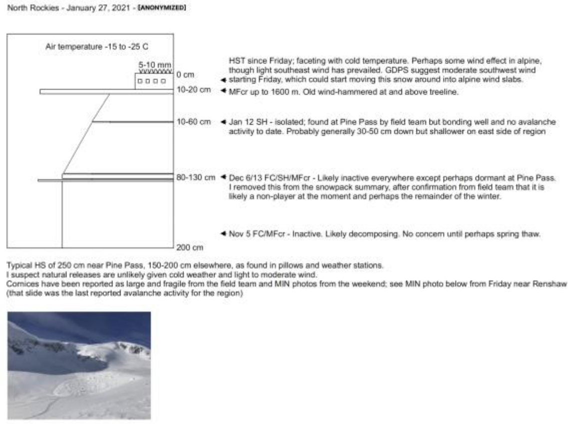

Figure 1: A representative snowprofile diagram annotated with forecaster's notes to better facilitate handoff.

4.2 Tagging Contextual Information

A custom-made screen capture tool (Figure 2) was developed to allow forecasters to record images and video during their workday and categorize them according to the type of contextual information being gathered. These “tags” included:

- **key evidence** that forecasters weighed heavily and influenced hazard assessments,
- new **uncertainties** that forecasters became aware of during the workday,
- **hunches** or suspicions forecasters formed based on little or weak evidence but that could nonetheless result in consequential outcomes, and
- **rationales for decisions** such as changes to the forecast bulletin that may be difficult to understand without further context which may include any or all of the prior listed categories.

Four forecasters were recruited to use this tool during an operational workday. First, forecasters were asked to capture relevant contextual information in their daily work using these tags. Collected media were stored in computer memory. At the end of the workday, forecasters were then instructed to reflect on the information they captured using this tool. Following this procedure, each forecaster was debriefed about their experience using this approach either in an interview using remote video conferencing or through email.

5. FINDINGS

Overall, forecasters found this exercise to be useful

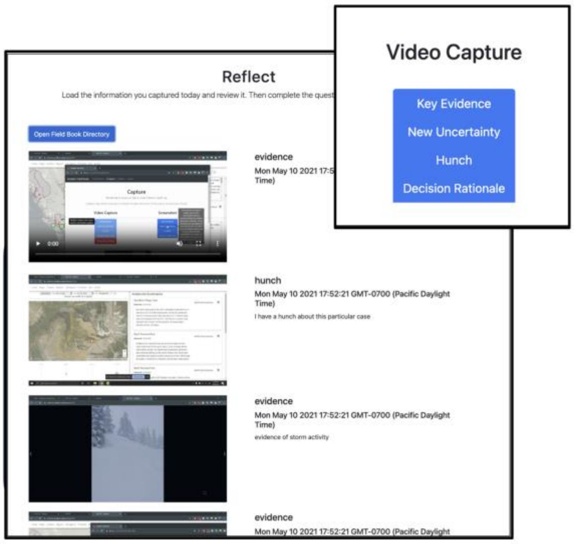

Figure 2: Screen capture tool to categorize and reflect on important contextual information gathered throughout the workday.

for helping them both realize what is important to communicate for handoff and articulate the benefits and outstanding challenges of the design approaches we explored. The following sections discuss core themes that emerged from our debrief conversations.

5.1 <u>Easy recognition, difficult articulation</u>

Overall, all three forecasters found tagging and capturing relevant information while working relatively easy. However, while recognizing important information was generally straightforward, articulating its significance was found to be more difficult. The forecaster who developed the snowprofile diagram described a time lag in being able to articulate the significance of information they noted.

> *"It took me… a few minutes to realize… sometimes I would say something, and then five minutes later… 'Oh, well, that's why it's important'… And then I would… go back to it… a little bit of a different mindset… But I found it very valuable… usually you only have like five minutes at the very end of your shift to do it… this process really helped me kind of hone-in on what is actually relevant to pass on [and] that'll improve my handover notes."*

Similar issues arose when forecasters were using the tagging tool. Forecasters sometimes found it difficult to pick the right tag category.

> *"It was all very easy to use. Sometimes I wasn't sure what [tag] to capture it with."*

Forecasters told us that while some tags like "uncertainties" or "key evidence" are common terms used in discussions between forecasters, "hunches" are not and were, therefore, harder to identify.

5.2 <u>Coordinating and planning work</u>

Forecasters found both tools to be helpful in identifying where to focus efforts and plan their workday. The forecaster who received the snowprofile as part of the handoff used it to identify and eliminate tasks that would be redundant.

> *"That was the last avalanche from a week ago… [reading avalanche observations] was immediately off my whole workflow… I wasn't gonna spend much time looking at weather stations or filtering through old InfoEx… this kind of shows that work wouldn't be relevant to the current conditions."*

At the same time, the snowprofile raised new questions for the forecaster to investigate.

> *"Sounds questionable whether or not that will be an avalanche problem. … I kind of want to look around at some of my own sources to see if I can find any more info on that."*

It also helped provide them with enough context to start weighing evidence.

> *"[It] gave me some context to kind of weigh that evidence against… [when there is] big uncertainty about either the weather forecast, or the snowpack structure itself… that's probably where there'd be more value in notes like this."*

Forecasters also found reflecting on screen captures they gathered using the tagging tool to be helpful for planning future work.

> *"What I'm flagging here is things that will prepare me to take a deep dive analysis tomorrow. Given the sparse observations and difficulty knowing the impact of warming as highlighted by these screen captures, I think my forecast tomorrow will be written to communicate uncertainty… and be a less prescriptive forecast."*

5.3 <u>Persistence of information</u>

A recurring challenge the forecasters raised throughout this project was that of determining how long information should persist in handoff information. Current practices result in information recorded in handoff notes being carried forward to days when it is no longer relevant. Forecasters explored potential solutions to prevent this from happening.

For instance, the forecaster who created the snowprofile described how the recency of when information in the snowprofile was last updated could serve as an important indicator for understanding its potential relevance or to highlight a need for further investigation.

> *"If you could sort of scroll back to what, what the notes were, like, three or four or five days ago to see what changes were made... stagnant old data, versus what was actually modified by the most recent forecaster, which is probably the most relevant data. I think that that would be important to highlight."*

Meanwhile, another forecaster discussed using snowprofiles as a way to set and direct tasks between forecasters much like a project management or productivity tool.

> *"[You could] put a red circle around… different weak layers [to indicate] 'maybe you can sort this out'."*

6. DISCUSSION & RECOMMENDATIONS

While work at Avalanche Canada is more office-based and more reliant on computers than in other avalanche safety operations, the challenges of collaboratively monitoring avalanche conditions, communication, and shift-changes extend to almost all avalanche forecasting contexts. We argue that capturing and linking contextual information to assessment decisions while working may improve team communication in a variety of operating contexts. However, we recommend that such approaches be tailored to that specific context to account for any application-specific needs.

Gathering contextual information relevant to hazard assessment during work may reduce the overall workload involved in writing hand-off notes while at the same time providing key details that would otherwise be difficult to recall or retrieve. Based on our experiences and lessons learned, we have the following recommendations for avalanche forecasting operations wishing to implement similar approaches.

6.1 Ensure system flexibility

While working, forecasters found it much easier to identify important contextual information than describe why it is important. This suggests that any system for gathering contextual information should not force the user to immediately categorize it as it may disrupt the work at hand. Instead, the system should allow the captured information to be categorized at a later point. Simply gathering it in the first place is likely to create value. Flexibility in organizing the role and meaning of gathered information will reduce disruptions.

We also recommend that the organization scheme used for gathered information should be flexible to meet the needs of different operational contexts. Our tagging system used thematic categories derived from information Avalanche Canada forecasters found important while forecasting. We do not believe that the themes we chose are the best or only way to organize gathered contextual information. Other operational contexts may have entirely different ways of thinking about and discussing hazard assessments. Further, through continued use, the categories used are likely to change over time as understanding about the best ways to organize information evolves to meet operational needs.

6.2 Focus on common discussion topics

Forecasters found it difficult to use tag categories for contextual information that are not usually explicitly named in discussions. While the terms 'uncertainty' or 'key evidence' were common and easily identifiable, the term 'hunches' was more challenging for forecasters. Introducing new vocabulary may lead to inconsistencies in how categories are interpreted and applied. Focusing on common topics that forecasters discuss already will likely result in more consistency.

While it was not an explicit part of our exploration, changes in hazard assessments like avalanche problems or danger ratings are some of the most discussed issues in avalanche forecasting. Any hazard assessments that are potentially difficult to understand for others can be clarified using contextual information captured throughout the workday as a rationale. This information could be made available in a dedicated dashboard for collaboratively monitoring hazard assessments, conditions, and forecaster reasoning processes in one place. This may help clarify the relationship between observations and hazard assessments to operational staff. Since there is an explicit and continuous record of this contextual information, it could also contribute to longer-term research efforts aiming to describe how forecasters use observations and highlight extraneous contextual factors in assessments that might affect how assessment data can be used in analysis.

6.3 Provide explicit collaborative support

Simply having access to contextual information helped forecasters to understand what work needed to be done and where to spend their effort. However, they also highlighted that additional collaborative support features could further help coordinate efforts between forecasters. For instance, having a change history of updates to a running record like a representative snowprofile could clarify which information is recent and most relevant. Similarly, additional features to allow forecasters to suggest topics for others to investigate in the future could help better coordinate efforts and streamline shift changes. We recommend drawing design inspiration from contemporary web-based productivity tools and collaborative work environments.

We note, however, that there may be potential pitfalls that might arise from the use of such tools. Such productivity tools introduce additional work overhead that may not always be needed. In any application context or situation, the benefits of supplemental work planning and coordination need to be weighed against the additional effort needed to implement and manage such tools.

7. CONCLUSION AND FUTURE WORK

Our explorations of approaches drawn from Collaborative Visual Analytics to address handoff challenges in a public avalanche forecasting context show great promise for improving the effectiveness of communication during shift changes. The key takeaway from this preliminary investigation is that capturing contextual information relevant to hazard assessment is a useful way to improve the efficiency and effectiveness of communication in forecasting teams.

The challenges of shift changes and shared work are not unique to avalanche forecasting and approaches drawn from other domains faced with similar challenges may prove valuable. In future work, we aim to further refine our designs and develop working operational prototypes to capture contextual information. In particular, we aim to explore how gathered contextual information may be linked to and used to clarify hazard assessments that could be difficult for other forecasters to understand.

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