A DECADE OF DATA DILEMMA;
THE DEVELOPMENT OF A RELATIONAL DATABASE AT ALTA, UTAH

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ABSTRACT: For over ten years Alta Ski Lifts Snow Safety has been developing software specifically for use within the ski area to assist in data collection, graphic display of the data, and archiving the data for query purposes. The primary goals of the software development are directed towards an easy interface to enable avalanche workers to query, with relative ease, any parameter before or after avalanche hazard reduction work. Other goals include transferring the data collected for educational uses to future avalanche hazard forecasters within the program and to assist in creating a daily avalanche hazard forecast. With the advancement of technology in personal computing and remote data acquisition, the possibilities have become infinite concerning what data to collect, the frequency of data collection, and what parameters are relevant to aide the worker in day to day operations. Weather, avalanche, operations, terrain, and snow pit data parameters are discussed. The developmental history of the software has been affected significantly as new programming tools have become available. Advances with hardware have created a perpetual process of reevaluating how much data is too much. This paper presents the past, present, and future development processes.

KEYWORDS: avalanche forecasting, avalanche types, snow accumulation, snow precipitation

1. INTRODUCTION

In the early 1980's the Alta Ski Area's, Snow Safety Department began archiving avalanche and weather data on a computer. The computer had 512 kilobytes of memory, 2-5¼ floppy drives, and a 300 baud modem. The computer cost US$5,000. At this same time, they invested in a Campbell Scientific CR21 datalogger and sensors that recorded remote wind and temperature data. As technology developed new tools at an alarming rate, decisions had to be made on a regular basis. Options on hardware, software, and remote data acquisition systems, have been, and will continue to be, very dynamic. The past, present, and future development processes are discussed in this paper.

2. HISTORY

The recording of weather and avalanche data started in the early 1940's, in and surrounding the Alta Ski Area. The United States Forest Service (USFS) was recording data for avalanche studies and operational needs for the safety of skiers in the Alta Ski Area. The USFS was responsible for avalanche hazard forecasting and control during this time. Wind sensors, hard wired into strip chart recorders, and air temperature sensors, attached to ink graphing devices, were introduced. All the data was recorded by hand in daily logs. The USFS had designed specific forms for daily recording in the late 1960's. Art Judson created the USFS West Wide Avalanche Network (WWAN) in 1967. It would significantly impact data collection and recording in the following years. Several locations began submitting the forms each month. The forms were collected to build a database. The forms were very lengthy and were not designed for computer entry. Knox Williams was hired in 1970. His task was to manage and expand the network. Forms were designed in 1972 on a standard 80-column format. The data was taken from the forms and keypunched onto cards, which were then processed by a mainframe computer at Colorado State University. The data was used to generate a monthly newsletter started by Judson and taken over (and named "Avalanche Notes") by Williams. The "Avalanche Notes" were compiled and mailed each of the winter months to 300 patrollers, snow rangers, scientists, and other members of the avalanche community. The data from the cards was then transferred onto 9 track magnetic tape.

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In the 1980's the punch cards were eliminated and the data was entered into a file that was written to disk.

Responsibility for the avalanche hazard forecasting program shifted from the USFS to the Alta Ski Area in the early 1970's. Knowledge of data collection and recording was passed on. This was the case with many programs within the avalanche industry. Each operation tailored their data collection and recording to meet specific operational needs. Few people, if any, at this time could foresee the upcoming advancements in technology. A complex decision process would be created by these advancements. What data do we collect? With what frequency do we look at this data? What data do we archive? Will this actually help make us better avalanche hazard forecasters?

3. DATA INTEGRATION

The first datalogger and sensors Alta Ski Area used in daily operations proved to be reliable. Collection of hourly, six hour, and twenty four hour data was collected from the top of the mountain. Data included: wind velocity and direction, maximum wind gust each hour, and average air temperature. Twenty four hour maximum and minimum values were also collected. The data was collected with the PC phone modem calling the datalogger site modem via 2 miles of a single pair of copper wires. The reports were printed out in columns from printable ASCII files produced by the datalogger. But what did the data mean to the forecaster?

No data has meaning apart from its context.

This new data had to be integrated into the forecaster's thought process. It wasn't as simple as talking to the night time grooming crew any more. Now there were columns of numbers on a white piece of paper. These numbers were samples from one place on the mountain. How did the data relate to the 250 avalanche starting zones the forecaster had to evaluate? No data has meaning apart from its context. In a ski area, "Ground Truth" verification is part of performing the hazard evaluation and avalanche control work. As the forecasters started to relate the data to what actually occurred, the tools became more useful. Once the forecasters became confident with the correlation of the data and reality, it was time to look forward. Where could these wonderful new tools help the hazard forecasters even more?

4. THE INITIAL DECISIONS

After the first winter of collecting remote weather data, it was obvious that the data helped forecasters make operational decisions. Discussions took place on what data the Snow Safety Department should archive. By 1982 improvements in mass storage devices for personal computers made archiving weather data feasible. Software advancements made the creation of databases a reality. A program named DBASE 4 was purchased. The questions were asked, "What types of data do we enter into the computer?" "How much data is enough?" "How much data is too much?" The data fields in the WWAN weather report sheets were used as a template. It was agreed that many of the data fields in the WWAN form were appropriate for day to day operations. It was believed that the time required to fill out the monthly reports to the WWAN could be reduced if the data was entered into the computer. Entering weather data into the computer seemed a natural progression, since the computer was being used to already collect data from the remote site on top of the mountain.

Avalanche occurrence data was the next consideration. Discussions on entering this data into the computer were quite dynamic between avalanche workers. There was no obvious contribution from a daily operational standpoint. Why should the time required to enter the data be spent by workers? It was agreed to start entering the data to help compile the monthly reports to the WWAN and track explosives usage. Discussions included visions of computer technology improving over the next 25 years and data was entered now would become usable. It was concluded that future avalanche forecasters could benefit from the data as advancements in technology occurred. Using the archived avalanche data might allow them to see weather factors leading to unusual and historical avalanche events. The WWAN report sheets were used as templates. Some data fields were deleted, others changed. The same customizing was performed with both the weather and avalanche sheets from the WWAN.

How far do we travel back in history? There was a large inventory of "hard copy" records in the Alta Area. With almost 40 years of records kept by the USFS in the Alta area, how far back should we try and record data in the computer? The decision

***Onno Wieringa was the Director at this time, Bill Hofman was Assistant Director, and Steve Rosso was an "Advisor".
was made that the database was being created for only the ski area permit area. The data would start from the first date that there were consistent weather records kept within the permit area.

5. THE SOFTWARE DEVELOPMENT BEGINS

The data started getting poured into the computer at a steady pace. Due to the cryptic nature of the DBASE 4 software, the audience of people who could look at it was limited. At times, with the usual computer "glitches" that we are all too familiar with today, progress was less than enthusiastic. A local skier at Alta approached the avalanche forecasters with a great interest in the project. He was interested in developing software for the weather and avalanche data. Roger Atkins began what turned into a nine year involvement. He began developing software, which in time, took on the name SnowBase. It was an equitable agreement; "code for skiing". As long as there were improvements in the software, Atkins would receive season passes at the ski area. Early in the archiving of data, everyone realized the key to effective databases was not just the technology. Yes, it was a significant technical challenge to build a database, select software, and educate workers. The return for that effort comes from what you do with the data. Just putting the data in a computer and providing software to access it wasn’t nearly enough. The main concern moved to keeping the amount of data to a usable level. Weather and avalanche data were keypunched into the database with "user friendly" entry screens. SnowBase had reached a point where it was a relational database. Users were able to view weather and avalanche data together.

Avalanche occurrence forms were developed for each control route within the ski area. The hard copy forms were improved to make recording less time consuming for the avalanche workers.

Snow profiles were now easily entered into the computer. Recording data from snow pits was faster in the field. Once back in the office, entering columns of numbers into the database returned nice looking snow profiles. Terrain data from each starting zone was collected and entered into the database. These included aspect, elevation above sea level, and degree of slope steepness. It was time again to align the technology with the program’s goals, strategies and processes. There are no technologies today or in the past that can do this for you. The issue that databases are only as good as the data they contain, had the forecasters...
reevaluate the data fields often. The quality of the data being entered was always scrutinized. Now we wanted to see a return from all the data entry. “Discovery Techniques” with the database had to be developed.

7. DATABASE ENGINEERING ACCELERATES

Advancements in technology and other operational factors allowed us to begin archiving hourly data from the remote sites. There were now four remote systems. The computer would call the stations on an hourly basis. The hourly data stream from the remote sites contributed greatly to the avalanche hazard forecast. We were now able to view interval snowfall, water equivalent, wind speed and direction, temperature, and relative humidity. Additional snow depth sensors reported total storm snowfall and total snow depth. SnowBase had not developed into a program that could ingest and graphically display this amount of data. There were limited query abilities and the routines were time consuming. There were over thirty avalanche workers that could potentially gain knowledge from the database. SnowBase was used by only four or five people in the program. There was not adequate time to use the database without interfering with daily operations. Roger Atkins was becoming more involved with heliski guiding in Utah and Canada. The time commitment necessary to keep improving the program was too great. We had reached a point with the database that it seemed like a fancy electronic file cabinet. We felt that all the work in SnowBase had proven useful, but it was missing the task of contributing to specific daily operational needs. With the increased volume of weather data and other database goals we redefined, we needed the support of the ski area management to take the next step. The commitment was a large one. Both in time and money. Many conversations with other avalanche forecasters and avalanche workers took place. The architecture of the databases contained in SnowBase would have to be redesigned. The goals of improving the database program included:

- Provide “Intuitive Navigation” for the user.
- Contain “point n’ click” filtering of records.
- Graph weather and avalanche data for a defined range of dates or filtered records.
- Structure the weather database in such a way users could view 24 hour, six hour, and one hour data graphically.
- Generate reports to file or print from a defined range of databases.
- Develop a database that integrated daily operational data with the weather and avalanche data.
- Develop a database for individual storm tracking.
- Improve the snow profile module.
- Develop a statistical database that can produce historical comparisons easily.
- Develop a query process that can look at individual records in all databases.
- Export any data in the program to a comma delimited ASCII file.
- Have the ability to customize reports from any of the databases.
- Compatibility with Local and Wide Area Network deployments.
- Include on line help and full program documentation.

Besides meeting daily operational needs, emphasis was to be on creating a tool that would help educate new and current avalanche workers. This wasn’t to replace the teaching that occurred between the workers. Nothing will ever replace the passing on of experiences, and actual field work between avalanche workers. It was believed that if the database became easy to use, new and experienced workers would be able to pick out certain parameters they were observing and see if they had occurred in the past. It was an “all or nothing” commitment since we were changing operating systems on the computer. To be certain the work was completed, Alta Ski Area would hire the programmer to work in the Snow Safety office over the summer.

We were given the support from our Company that was necessary to continue. The search for a new programmer began.
8. A NEW PROGRAMMER IS FOUND

We didn't have to go very far to find the person. Randy Trover worked as the Assistant Snow Safety Director at Snowbird, Utah. He had a strong interest in programming and felt he was qualified for the project. Alta Ski Area hired him for the summer months. Howlett and Trover had experience with different operating systems and programming software. The first task was finding the correct platform to perform the programming. We feared technology could outrun the chosen platform. We couldn't put all our resources into a platform that might not work in three years. Trover suggested a relatively new platform at that time; Borland's® Delphi™. Further research showed that it had great promise over the next several years. Third party tools were being developed for Delphi™ that would help the programming process. Delphi™ was purchased and the programming started. The new program would be named SnowJob.

9. THE PROGRAMMER’S PERSPECTIVE

Why did we choose Delphi™?
- Compiled Language.
- Full access to Windows® API.
- Prior experience in the base language of Delphi™, Turbo Pascal™.

DESIGN CONSIDERATIONS

Data to Information was the main goal. This drove all other processes. The critical concept was for SnowJob to present information through intuitive navigation to the end user. This meant the user had an easy method that flowed from one task to another. I was focused on creating a desktop that allowed forecasters to access all the information and tools at all times. The format had to not intimidate the user. Also, to present the desktop in a way that the different databases related to each other. Information needed to be presented to the user in a way that made sense and lead to a greater understanding of the “big picture”. Examples of this concept are the way the graphics execute. You can start with the largest scale graph, and then step through different time lines. Starting with 24 hour graphs, then to 6 hour, and finally to 1 hour. During these steps in time, you can maintain your links forward and backward, while having access to the most important information from each period at your finger tips.

DATABASE STRUCTURE

- Databases were structured with emphasis on queries.
- Databases were first taken to the “3rd normal form”.
- All keys, relationships, constraints, and domains were defined.
- Data was then “denormalized” to make the most important information available to query processes and report creation.
- Occasionally, “normalization” leads to data fragmentation that requires extensive programming and processing power to convert data back into information. Part of the structure was to “pre-query” commonly accessed data and store them in the database. This made certain types of queries only have to display the data that had already been processed.
- “Always on top”; a design that would allow unbroken access from one database to the other. No matter which database you were working with at the time.

APPLICATION ARCHITECTURE

- Open-ended; Not to integrate everything so tightly that changes to one module, required an entire program rewrite.
- Each module was built on a base object that encapsulates basic database, and interprocess communication protocols.
- Each base object in turn is part of the overall Application Object that manages the low level interplay of each process. This allows the application as a whole to be tightly integrated, but not totally dependant on some other process that might not be available.
- The processes above, allowed new modules to be easily plugged into SnowJob.
- Changes and upgrades are easily added to an extensible framework that is consistent across the entire application.
- Each module has the ability to stand on its own.

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Work information that was to be persistent was stored. Queries and filters were stored in the database tables. Codes, constraints, and other changeable parts of the application were stored in tables.

**GRAPHICAL INTERFACE**

Although the math behind these graphics may make your eyes glaze over, the practical application of graphics is the heart of the database. Without “discovery techniques”, there is no effective analysis. Without effective analysis, how can one possibly make sense of gigabytes of data and consistently gain knowledge? By using graphics, one can transform data into knowledge about your environment—both better knowledge of what has happened, and insight into what may happen. Graphic display of data provides a fast and easy way for data to be transformed into knowledge, then to be delivered to a wider audience. The Snow Safety Department would not realize the full benefit of SnowJob if it was to rely on a small group of highly skilled computer users to service the entire staff. Every product was developed with input from avalanche workers. The key to integrate computer produced products into daily operations was to get opinions from as many non-computer users as possible. The final products were designed, for the most part, by workers that did not use computers.

9. CURRENT DAY PRODUCTS

SnowJob is working on a daily basis in the Snow Safety program at Alta. Many of the tasks it performs are automated. The payoff of all the money and time invested is starting to be realized. Real time graphic display of weather, avalanche, and terrain information is available. Measured parameters and derived parameters are produced. Each computer that is running the program on the Local Area Network (LAN), can customize what reports get automatically output to the printer. There is a computer in the ski patrol locker room that is available to all avalanche workers to query. Information is piped out to the LAN for any worker in the company to look at current mountain weather, or browse through a click n’ point calendar to review snow totals from years past. To publish all the graphs and capabilities of SnowJob is beyond the scope of this document. The following pages contain figures of some of the highlights of the program. To fully appreciate the capabilities of this tool, one has to sit at the computer monitor.

A floating menu bar allows the user to launch modules at any time. There are seven databases at the time of this paper. An eighth database is being added to maintain and access images of avalanches.
The Calendar allows users to click through sequential years, months, and days. The YTD and MTD totals auto calculate new values for the range defined. Total Class 2 or better, new snow avalanches are shown in the upper left corner of each day. Old snow avalanches appear in the upper right hand corners.

The daily weather screen displays 24 hour, 6 hour weather data, and 24 hour avalanche information. Any field can be filtered to setup specific queries. All the screens within SnowJob have this capability. Filters can then be named and saved for use at a later time. The tabs on the top of the screen allow the user to click between the entry/edit screen, the weather/avalanche viewer, six hour weather (Detail Wx), and hourly weather databases. Navigation is cloned in all screens. To go directly to the date 11/01/1982, the user types 821101. On dates that old snow avalanches are recorded, the text on the line is red.
The weather and avalanche viewer displays each avalanche occurrence record of the day you highlight. The ability to filter weather and avalanche data on the same screen helps the user define additional queries.

Some fields for daily weather information are still manually entered. The screen duplicates the hard copy form that is used daily. Comments are critical for future query results. Some of the fields contain subjective data from the forecasters that will never be imported automatically.
24 HOUR TIME SERIES graphs weather and avalanches for the defined range. Note the arrows on the top header. Once a range is defined, the user can go back or forward in time. The graph scrolls the same range in time the user defined initially. This allows the user to go over many years in a short period of time and “zoom in” to unusual events. This also offers a valuable tool for error checking the data.

6 HOUR TIME SERIES contains more detail of each 24 hour period. If there are more than two 12 hour time periods with precipitation, the totals are “smoothed” and graphed. Periods with greater than 10 inches of accumulated snowfall are totaled. Due to the scaling, 10% density snowfall graphs evenly with the water equivalent line. This enables a view of snowfall density that occurred during the storm. Wind is plotted in 6 hour intervals. Total snow on the ground allows viewing settlement over time. As with other weather graph windows, users are able to go back or forward in time. Snow and water totals are recalculated with each time period. Different periods of time can be totaled by defining a range on the bottom x-axis.
HOURLY TIME SERIES is completely automated by ingesting remote data. The graph is designed for operational purposes and has a maximum capacity of displaying 36 hours. Temperatures at two elevations are in the top frame. Wind velocity, direction, and maximum gust, are depicted on a “Wind Ribbon”. The arrows point into the wind. The hour average velocity is the bottom line of the ribbon. The maximum gust is the top line. This provides a unique look at the wind patterns and trends. Different locations of wind data are graphed in the same window by clicking a button. The interval snowfall depth sensor is cleaned every 12 hours. Snowfall and precipitation intensity are easily viewed. When users navigate forward or backward in the defined time range, snowfall and water totals are automatically recalculated.

Wind roses can be created in any weather data screen.
Avalanche Viewer allows powerful filtering of records. The user clicks on any of the field headers and a pop up box lets them enter the range of alpha or numeric characters they require. Instant information on avalanche paths or shot numbers is available. "Double clicking" on the Path field, every avalanche, Class 2 or larger, are totaled by size for the history of that path. Individual shot numbers can be double clicked and have the same report generated. Navigation is cloned and operates the same as the weather modules. Defining a range of time generates different summaries and reports. Entries with comments are depicted by red colored text. Filters can be named, saved, and recalled at a later time.

THE AVALANCHE ROSE takes a user defined time range, then queries the avalanche and terrain databases. Designed for color printing or monitor viewing, new snow and old snow avalanche occurrences are denoted by color. Users can click on the top header and define what size and type of avalanche they want to appear on the graph. Having an extensive terrain database is required to produce this graph.
The OPERATIONS database was created to record avalanche control missions and avalanche closures. Avalanche closures outside of the ski area that directly affect the ski area are recorded. Data from the operations database are included in weather reports that are generated.
SNOW PROFILES are entered with three different windows. Shown here is the main screen where users can add or browse through existing profiles. Layers/Notes are entered in separate windows due to their complexity.

An example of a snow profile. Users can go through multiple profiles with a keystroke.
THE STATISTICS module creates historical reports that relate to defined ranges of time. There are four different screens that each allow different formats and options to the user. Defining a query over a number of days is particularly useful during long duration storms.

Entering the current weather parameters and duration of the current storm, quickly matches any similar storms. One can then click back to the graphic weather displays and isolate individual events.
COMPLEX SQL QUERIES are defined in a “drag n’ drop” environment. Databases are linked together and reports are generated without the user having prior experience in the SQL platform. Queries can be named and saved for use in the future. The Query module is the most powerful tool in SnowJob, however it is also the most complex and time consuming to use.

10. CONCLUSION

What began as a vision almost 20 years ago, is now reality. The foresight and commitment to begin entering data and develop software made the current products possible. Remote data collection and the SnowJob software is an indispensable tool for the hazard forecasting program at Alta. To have data transformed into information without hours spent in front of a computer, contributes significantly to the decision process. Using the software in an educational application is in it’s infancy. It shows great promise in the future. Technology is not trying replace a forecaster’s ability to apply all the variables. However, it does enable access to current and historical data during the forecast processes. This has, and will continue to, improved our avalanche hazard forecasts.

Avalanche forecasters are still being killed in avalanches. Whether the deaths are from poor judgement due to lack of education, or from unique avalanche events, they still occur. Integration of technology into daily operations can help the forecast community improve. Scientists continue to work on other discovery techniques. These include techniques such as clustering, factor analysis, neural networks, decision trees (CHAID and CART), genetic algorithms, rule induction, and fuzzy logic. As contributions from practitioners and scientists continue to merge, avalanche professionals should look forward to the challenge of applying these advancements to their forecast methodologies and daily operations.

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