SLALOM PROBING - A SURVIVAL CHANCE OPTIMIZED PROBE LINE SEARCH STRATEGY

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ABSTRACT: Probe line searches are an important tool for organized avalanche rescue. Since electronic search means or avalanche dogs are not always available, probe line searches still need to be applied. In France, the percentage of buried subjects which were found by probe lines in the period winter 2001/2002 to 2010/2011 was 13.2% and decreased for the period 2006/2007 to 2010/2011 only to 11%. As survival chances of avalanche burials drop rapidly with increasing burial time, the biggest drawback of probe line searches are their slow area search speed. Since the efficiency of a rescue system is based on its potential to save lives, it is important to find the highest survival chance of an avalanche burial as a balance between area search speed and probability of detection. The ICAR Avalanche Commission task group “probe line strategies” therefore further optimized the current probe line search methods. Analysis of the physical effort and efficiency of the rescuer lead to the “Slalom Probing” method. Within this approach each rescuer covers a 1m broad strip of the avalanche debris which he or she probes walking in a “slalom” pattern across the strip. The method is designed with sufficient error tolerance to allow for uninterrupted flow of the probing activity. The rescuer always probes right in front of his or her body, perpendicular to the slope angle. The total ergonomic and organizational benefits of our new method lead to 33-50% increase of the probed surface compared to existing probing methods.

KEYWORDS: Avalanche Rescue, Probe Line, Survival Chance

INTRODUCTION

Many people still venture in winter backcountry without a beacon or Recco and – in case of an avalanche accident - need to be searched for by avalanche dogs or a probe line. Avalanche dogs are not everywhere readily available and their probability of detection depends on various variables. It is therefore indispensable to keep organized rescue teams trained in efficient probe line search strategies. Within the ICAR Avalanche Commission, a survey made obvious that the different member organizations believe in and apply a wide variety of probe line strategies. A task group within the avalanche commission has been set up in order to analyze the situation, optimize the existing systems and propose a standardized approach for coarse and fine probing. As outlined by Auger and Jamison (1996), an important factor of the performance of a probe line search strategy is the amount of probe holes a rescuer is able to do within a certain timeframe. Their study concluded that 3-holes-per-step methods are more efficient than one or two holes per step methods.

The overall performance of a probe line search strategy includes the following parameters:

- Probability of detection
- Physical and mental demands on rescuers (ex pected sustainability / endurance of the rescuer)
- Requirements on minimum level of training
- Area search speed derived from the method specific “holes / minute / rescuer” ratio.

The study therefore focused on optimizing the “holes / minute / rescuer” ratio and the organizational measures which assure a most optimal use of the available workforce.

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METHODS

Analysis of the factors leading to early fatigue, waiting times and mental frustration

In order to achieve a high and sustainable "holes / minute / rescue" rate, the factors leading to early fatigue, waiting times and mental frustration had to be studied, field tested and analyzed. In an approach very comparable to the initial steps during the development of the v-shaped snow conveyor belt, the entire process has been split up in its individual components. These components were individually analyzed, in particular using video monitoring during field testing. In an incremental iteration approach, the following physical activities and organizational processes have been analyzed and optimized:

- the step forward
- lateral movement
- probing in front of the rescuer
- probing on the side of the rescuer
- probing in different angles to the snow surface
- probing on different slope inclinations
- orders given by a dedicated probe line leader
- orders given by a rescuer who is part of the probe line
- precision of probe hole spacing
- systematic offset in the second passage

During field testing, unfortunately we could only work with five to ten minute probing samples due to resource and time restrictions. Therefore, we expect that some of the key advantages in ergonomics of Slalom Probing did not become visible in their full extent. However, in a real organized rescue mission, where rescuers often need to probe for an extended period of time, systems which have been designed with great emphasis on using the available workforce in an as sustainable manner as possible, will for sure be appreciated by rescue personnel and contribute to faster search times. In each 5 to 10min sample, the following data was recorded:

- number of probe holes
- number of lines
- number of rescuers
- hardness of debris in a 4 step scale
- forward distance covered within the given timeframe
- amount of required realignments

Based on the measured forward distance, the average length of the step forward was calculated.

RESULTS

Performance in "holes per rescuer per minute"

The probing rate decreases with increasing burial depth, the current field test database shows:

120cm probing depth: 17 holes/min/rescuer
150cm probing depth: 12 holes/min/rescuer
180cm probing depth: 10 holes/min/rescuer

These numbers are comparable to the "3-hole-per-step" method.

Steps forward vs lateral motion

Steps in forward direction, in particular on inclines slopes, have shown to be much more time-consuming than lateral motion. Furthermore, steps forward are more likely to have great variance in length, in particular influenced by slope inclination and the personal step-length. On the other hand, lateral steps have proven to be very well applicable independently of slope inclination and there is only marginal variance in the side step length, in particular side steps which are by far too long are physiologically almost impossible or at least very uncomfortable.

Efficiency of different probing positions relative to the center of the body of the rescuer

As there are probing systems where the probe is always applied exactly in front of the body of the rescuers, systems where the probe is always applied off center of the body and systems where both methods are combined, we evaluated in the practical field test which working position is most efficient and sustainable when larger surfaces need to be probed. It became very clearly visible, that applying the probe straight in front of the body of the rescuer is by far more ergonomic than any other probing position, including the slightly diagonal approach which is taken by the original 3-holes-per-step-system. The more probing depth is increased, the harder the debris are and the more inclined the slope angle is, the more strenuous it is for the rescuer when the probe has to be applied in positions different than exactly in front of his body.

Influence of different probing angles in respect of slope inclination

By surprise, we discovered that probing perpendicular to the snow surface represents as well for probe lines the most suitable probing angle.. The discovery is an excellent example that systematic video monitoring of the field tests is indispensable in modern field research in avalanche rescue and that all work positions must be videotaped, even if the obvious focus of the test would not indicate this. Working probe lines were videotaped laterally along the probe line. We started the field testing applying the current standard probing angle "straight down" (to the center of gravity). As long as the probe line moves in more or less flat terrain, this is efficient. However, as soon as the probe line had to work in inclined terrain, we discovered by surprise that the probes systematically get dynamically bent towards the mountainside each time the rescuer was pushing it into the snow. The analysis of the force vector the human being by its physiology applies to the probe explains why the probes systematically are bent towards to mountain side. Although the bending is in the dynamic deformation range of the probes, the bending energy gets lost each time the probe is pushed into the debris. Another contributing effect is the fact that the rescuer standing on an inclined slope get slightly out of balance each time he pushes the probe into the snowpack.

Length of the step forward and the side steps

The length of the step forward often is in average considerably too long whereas the width of the sidesteps are in average within an acceptable deviation from the 50 cm pattern.

DISCUSSION

Based on the finding that lateral motion turned out to be less time consuming than controlled forward steps, one rescuer should cover an area which is as wide as possible. This confirms the findings of Jamieson and Auger (1996), who have proven that probe line search systems with 3 holes per step have shown a considerably greater efficiency compared to probe line search systems with one or two hole per step. We did not try a 4 holes per step approach, as we believe that it is impracticable if the distances between the rescuers in a probe line cannot be measures by a very simple and fast procedure such as "aligning wrist to wrist".

Optimal probing position

The field tests clearly showed that probing is less trying when the probe is applied straight in front of the rescuer. Instead of reaching out to the side to probe or probing diagonally, the new "Slalom Probing" method suggests making a small side step to move the rescuers position to the next grid point. Probing straight in front of the body has the additional advantage that the probe can be much better controlled in angle as well as more gently guided in hard debris.

Optimal probing angle in respect of slope inclination

In order to stay in balance while probing on an inclined slope, the force vector to stay in balance and the force vector to push the probe into the snow pack need to be in the same axis. This is possible when the probe is always applied perpendicular to the slope inclination. Video monitoring the probe lines applying the probe in this manner clearly show that the probe does not get bent, therefore the entire force is used to push the snow into the snowpack and the rescuer manages to stay much more comfortable in balance independently of slope inclination.

Measures to keep the 50x50 cm grid sufficiently precise

Acceptable precision of the 50 cm step forward could only be achieved by pushing the tip of the probe gently into the snow 50 cm ahead of the previous row *before* the physical step is made. Without this simple, but effective procedure, the step forward was in the majority of the cases by far (70 to 90 cm) to long, in particular in the less inclined sections of the terrain. Without measures to control the length of the step forward, rescuers clearly have the tendency to apply a step length given by their individual physiology.
There was no indication during the field testing, that special measures to control the length of the lateral steps would be required.

Required periodicity of realignments and realignment procedure

In average, a realignment during the field testing was indicated after approx. every fifth "slalom", however, there is no reason to give a clear recommendation concerning this as it is individual to the complexity of the terrain and the training level of the rescuers. The command to realign should only be given when there clearly is a requirement for it. As a general tendency the higher the training level with the proposed method the longer the rescuers will stay "on track" and therefore the longer time-consuming realignments can be postponed. During the realignment procedure, the rescuers stick the probe into the snow so that they can move freely. Realignments are made backward to the positon of the last rescuers, never forward as this would leave terrain unsearched! The command is "align left to right". The rescuer on the left end of the line, immediately raises his arms sidewise. The remaining rescuers wait and look to their left. They only raise their arms when the rescuer directly to their left has raised his arms. This is important as realignments become terribly inefficient when rescuers try to realign from multiple reference points.

Organizational findings

It is required that one rescuers is in charge of the probe line and gives the commands. Best results were achieved when the probe line leader was part of the probe line and took a position in the center of the line. Like this, the voice of the leader is best heard by all rescuers and the commands are given in a pace which is adapted to probing depth and hardness of the debris. Commands given by a probe line leader who is part of the line lead to a more efficient use of the workforce as the line probes in a sustainable pace.

CONCLUSIONS

The discussion on the various variables which influence the overall performance of a probe line search strategy leads to the conclusion that methods which demand a high level of precision and compliance lead to more frequent interruptions of the individual work flow. This lowers the motivation and endurance of the rescuer and ads time for the realignment measures.

Probability of detection (POD) with a 50x50 cm grid is simulated to be 88 % on the first pass, whereas a 60x60 cm grid shows a reduced POD of 75 % in the first pass (Ballard and Atkins, ISSW 2004). This proves that the impact of some imprecision which may build up locally between realignment cycles only have a very marginal impact of the overall POD. A fundamental consideration behind the "Slalom Probing" approach is that it is more efficient to work with a fairly fine base grid, but allow for as much flow as possible while the line in running. Even if this may lead to some offset from the grid, the 50x50 cm base resolution is fine enough to be fairly user error tolerant. Old-style rescue and probe line leaders may have to accept that military style probe line procedure look nicer organized, but probably save less lives - or in other terms "it does not need to look nice, it needs to save lives".

For mountain rescue, benefits of "Slalom Probing" are as well reduced exposure time due to faster search results and a more ergonomic approach to strenuous rescue technique.

First pass probing depth and second pass grid offset

Preliminary results of a full scale avalanche rescue simulation show that for a survival chance optimized probe line search strategy, probing depth should be limited in the first pass to 1,5m (fig 1). When a second pass needs to be applied, a grid offset is required. A systematic offset of half of the grid width is hard to control. Furthermore our field tests have shown that in a second pass, a rescuer often falls back in the pattern of his first pass. We therefore clearly recommend introducing the offset in the second pass by changing the position of the rescuers in the line. Every rescuer seems to have a slightly individual probing pattern based on his physiology and therefore this seems to be a more reliable grid offset method.

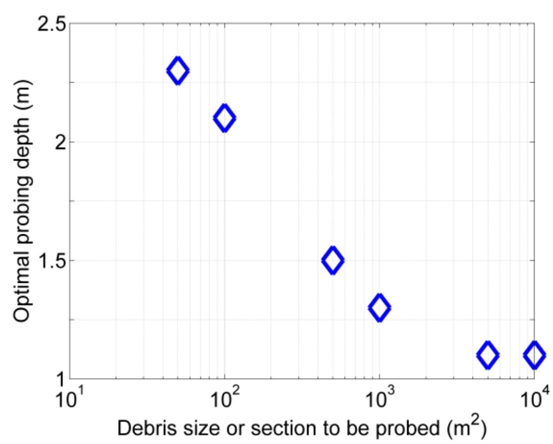

Figure 1: Most survival chance optimized probing depth in the first pass for different sizes of the probed section of the debris.

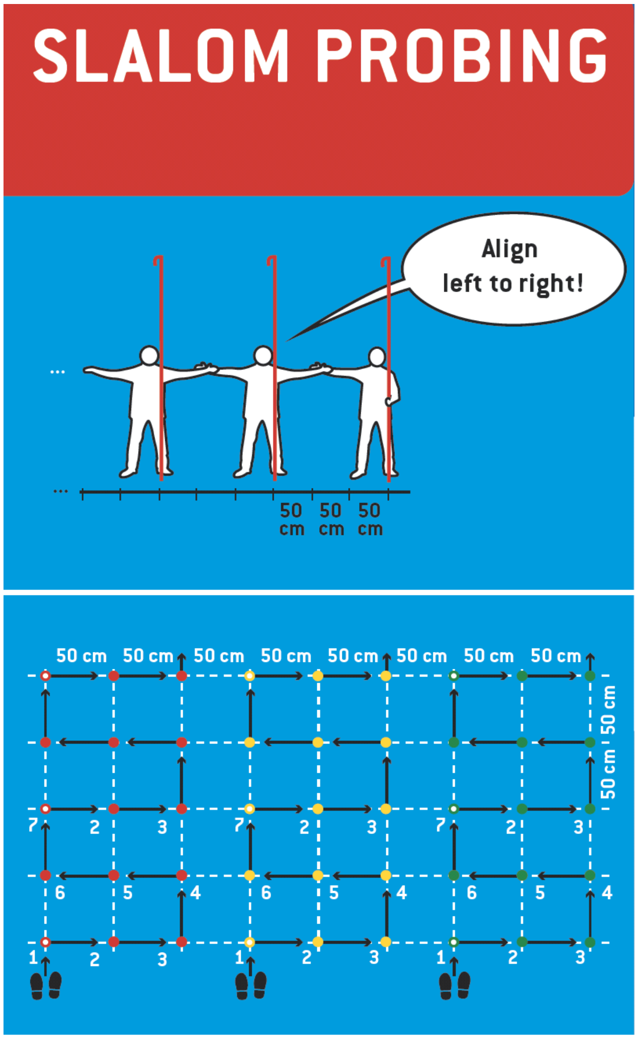

Illustration 1: “Slalom Probing”
Instructions with alignment procedure, probing grid and chronological progression in the “slalom”

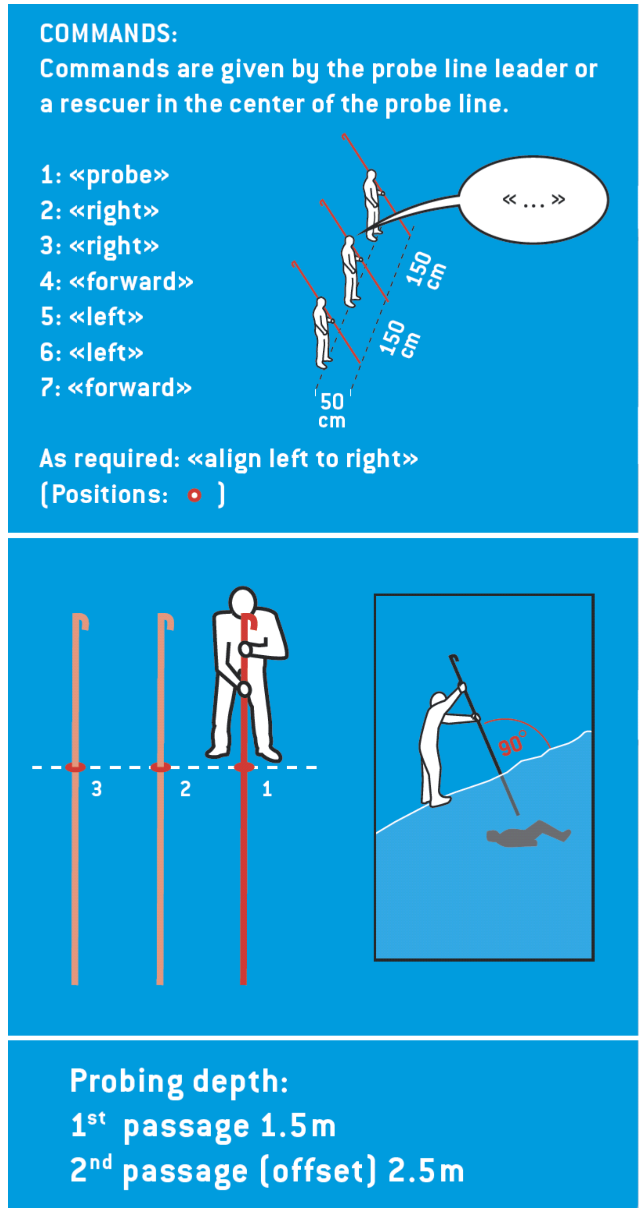

Illustration 2: “Slalom Probing”
Instructions with commands, probing position, slope angle adaptation as well as specific procedures in first and second passage

Grid reference tools

Although we did not measure the impact of special rope and net systems designed as grid reference, we believe that they only degrade the overall performance of a survival chance optimized search strategy for human beings. Only if the physical dimension of the search targets would be much smaller than a human body, the application of such grid reference tools might show a positive influence on the overall performance.

Probe line search systems for by-standers

The list of factors which influence the overall performance of a probe line search system includes the factor "minimum required training level". We believe that "Slalom Probing" needs to be instructed and applied for 15 min (in total) outside of a real rescue situation in order to reach the required minimum threshold. In cases with no prior training and sufficient resources readily available, such as reported in the past from inbound ski area avalanches or accidents in very popular snowmobile or skitouring areas, we recommend to apply the old style "one hole per step" method by lining up the volunteers shoulder by shoulder and use the qualified rescuers to command, supervise and involve as much of the available manpower as possible.

Future steps

The reference database for "Slalom Probing" should be extended by additional field testing. Furthermore, we would like to quantitatively measure the arbitrary offset from the grid in the first and second pass. Applying and extending the model of the full scale avalanche rescue simulation originally developed to calculate "The Survival Chance Optimized Search Strip Width" will lead to a greater level of understanding how "Slalom Probing" can be further fine-tuned based on retrospective statistical survival chance analysis.

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