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Risk Assessment for Slope Monitoring

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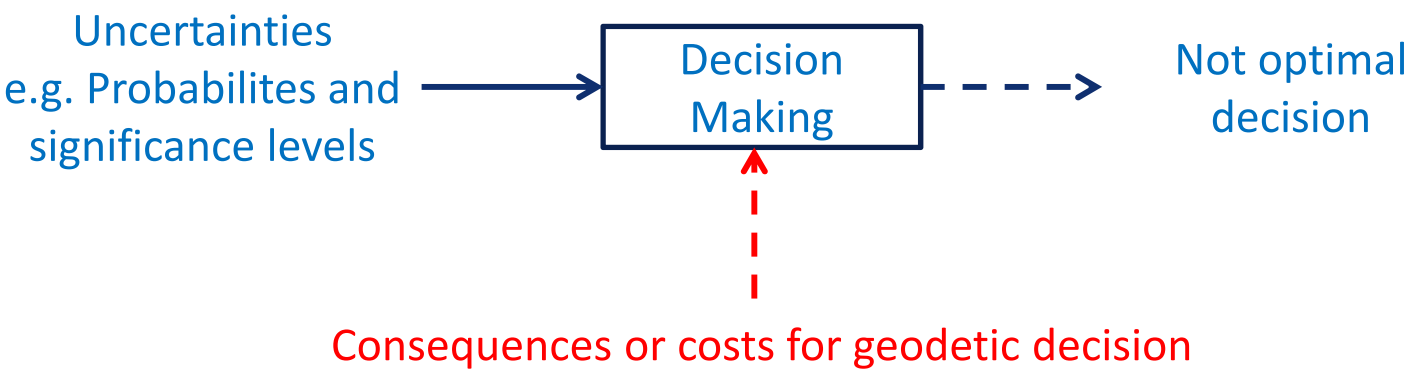
- **Main goal of geodetic deformation monitoring**

  - Minimizing the risk of unexpected collapses of artificial objects and geologic hazards.

- **Current situation and problem**



Agenda

1. Motivation
2. General idea of the methodology
3. Example: monitoring of a slide slope (Hornbergl)
4. Conclusion and prospects

➢ Utility theory

Main idea: to judge each possible decision with a utility value.

- Possible situations:

• U_{00}, actually satisfies the null hypothesis H_0; (correctly) classified as the null hypothesis H_0.
• U_{01}, actually satisfies the null hypothesis H_0; (incorrectly) classified as the alternative hypothesis H_1. (Type I error)
• U_{11}, actually satisfies the alternative hypothesis H_1; (correctly) classified as the alternative hypothesis H_1.
• U_{10}, actually satisfies the alternative hypothesis H_1; (incorrectly) classified as the null hypothesis H_0. (Type II error)

Decision making with cost functions

- To apply the decision making approach, they must be known:

- $\rho_0(T)$ and $\rho_1(T)$ are probability densities functions of null and alternative hypotheses.
- $P(H_0)$ and $P(H_1)$ are probabilities for a randomly chosen object satisfying null and alternative hypotheses.

-The probability for a test value T which satisfies the null hypothesis can be determined using Bayes' theorem:

$$p_0(T) = P\left(H_0 \middle| T\right) = \frac{P\left(T \middle| H_0\right) \cdot P\left(H_0\right)}{P\left(T \middle| H_0\right) \cdot P\left(H_0\right) + P\left(T \middle| H_1\right) \cdot P\left(H_1\right)} = \frac{\rho_0(T) \cdot P\left(H_0\right)}{\rho_0(T) \cdot P\left(H_0\right) + \rho_1(T) \cdot P\left(H_1\right)}$$

$$p_1(T) = P\left(H_1 \middle| T\right) = 1 - p_0(T) \text{ (i.e. regulatory thresholds)}$$

Decision making with cost functions

- The expected utilities of null and alternative hypotheses:

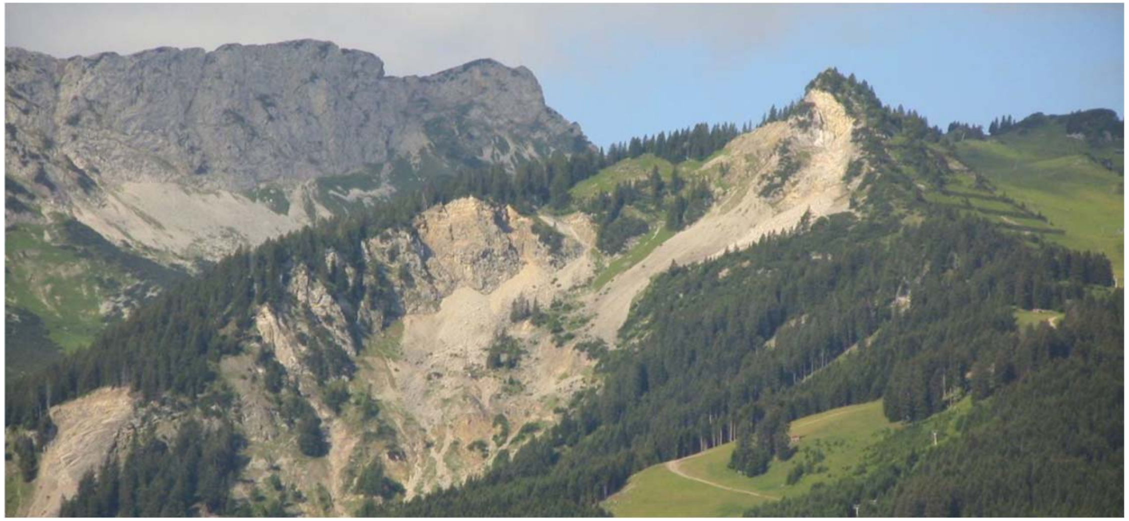
$$K_0 = p_0(T)U_{00} + p_1(T)U_{10} = p_0(T)\left(U_{00} - U_{10}\right) + U_{10}$$
$$K_1 = p_0(T)U_{01} + p_1(T)U_{11} = p_0(T)\left(U_{01} - U_{11}\right) + U_{11}$$

-The Neyman-Pearson criterion :

- Test value is classified to null hypothesis, if $\frac{\rho_0(T)}{\rho_1(T)} \geq r_0 = \frac{(U_{11} - U_{10})p_1(T)}{(U_{00} - U_{01})p_0(T)}$ holds.
- Test value is classified to alternative hypothesis, if $\frac{\rho_0(T)}{\rho_1(T)} < r_0$ holds.

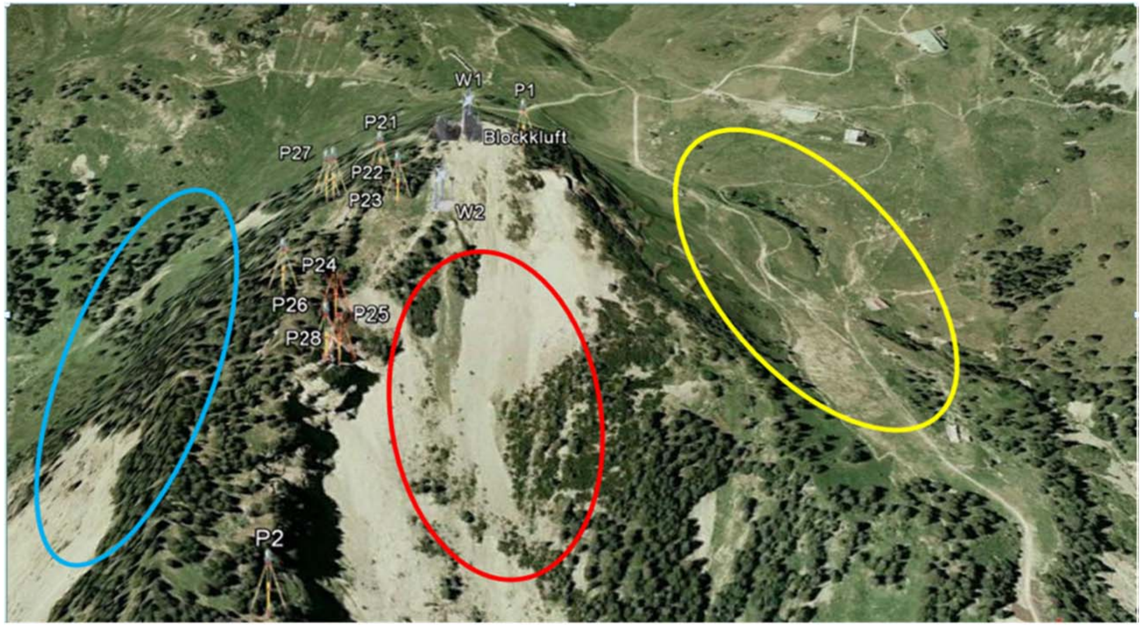
→ Make optimal decision with minimum costs or/and try to minimize the risk of an individual project.

Introduction of Hornbergl



- Location: near Reutte, Tyrol (Austria).
- Altitude: 1755 meters.
- South slope: massive fissures and crevices.
- Monitoring approach: GPS/GNSS

Introduction of Hornbergl



- Monitoring points:

Types	Location	Possible damage
I	near skiing field	facilities, people
II	near the trench	dams, buildings, farmlands
III	other side of the valley/far from town	small rivers

Example: monitoring of a slide slope (Hornbergl)

- **Steering procedure**

- Specific information to know:

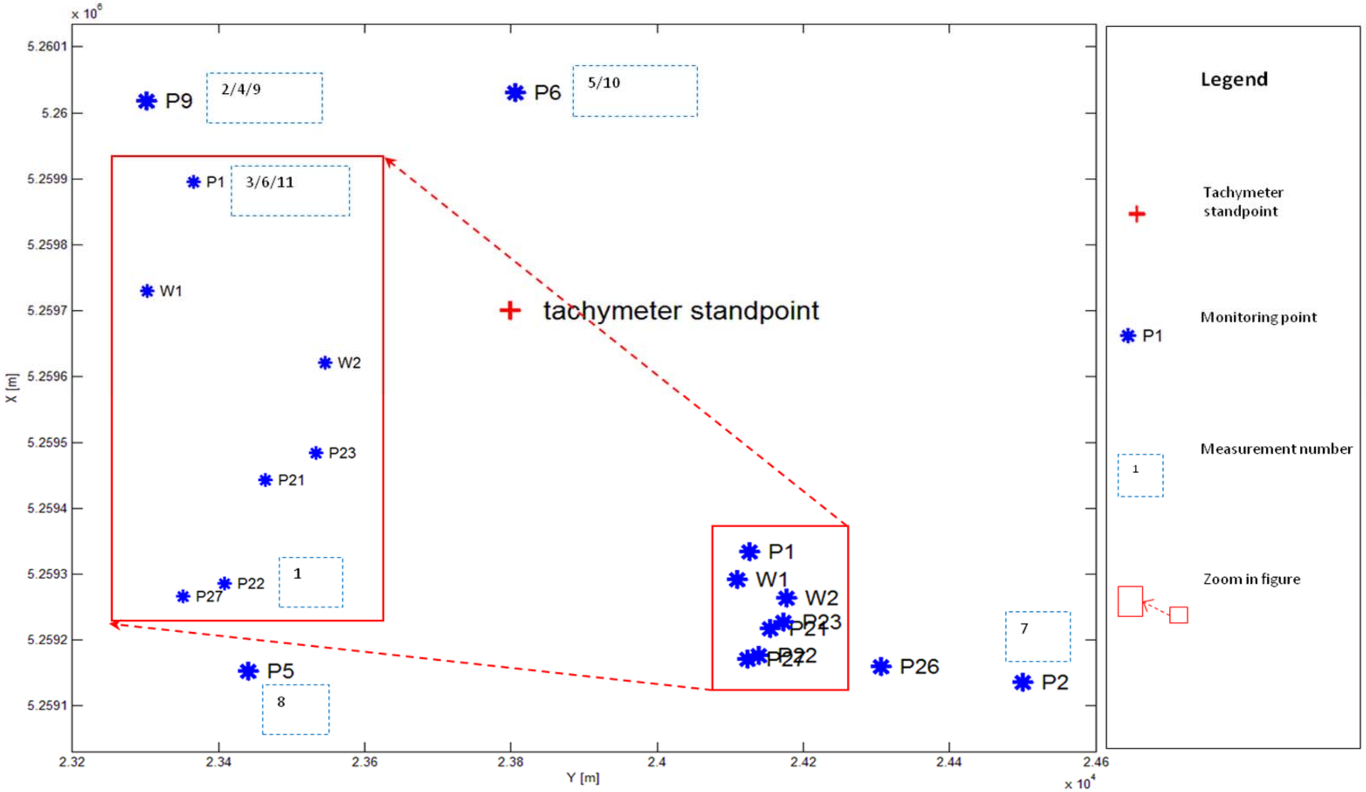
- The alternative hypothesis in deformation monitoring is usually not known.
- The pdf of null hypothesis is often based on the observations.
- Here: regulatory thresholds are applied.
- Only theoretical uncertainties are considered in this study.

- In order to decrease the risk and the negative environmental impacts, the monitoring of the slope in this study is additionally carried out with tachymeters.

Steering procedure

- With standard deviations of movements, get K_0 and K_1;
  $K^{min}=\min\{K_0 , K_1\}$.
- With simulated additional measurements, get K_0^s and K_1^s;
  $K^{min,s}=\min\{K_0^s , K_1^s\}$.
- Pick out the monitoring point with $\max\{ \Delta K^{min} = | K^{min} - K^{min,s} | \}$ as real additional measurement.
- Estimation for coordinates.
- With standard deviations of movements, get K_0 and K_1 again;
  $K^{min,1}=\min\{K_0 , K_1\}$.
- $\Delta K^{min,1} = | K^{min} - K^{min,1} |$ and $K^{min,1}$ is assigned to K^{min}.

➤ Results



→ The measurements of the points lead to the minimum risk for the project.

Conclusion for current results

- Consequences / costs can be considered in geodetic decisions.
- Find next optimal measurement to reduce risk of an individual project.
- Utility values and thresholds are intuitive.
- influence factors: standard deviation of movements, distance from monitoring point to stand point, thresholds, utility values, etc.

Prospects

- More precise/reliable utility values and thresholds are helpful.
- Consider both K_0 and K_1 together.
- Study the change trends of K_0 and K_1.
- Apply this strategy for a more reliable project.
- Extended the strategy. E.g. multiple criteria decisions, define thresholds with transition regions, etc.

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Thank you for your attention.