Prediction model to identify the significant development periods of the historical objects

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Syllabus

1. Goal of the project
2. Reconstruction of the historical object
   - materials collection
   - data selection and classification
   - data preparation (reconstruction in MicroStation, geo-referencing in ArcGIS)
   - output in ArcGIS: set of layers in historical periods
3. Design of prediction method
4. Set significant development periods of the historical object
5. Outputs, presentations
1. Goal of the project

To propose a method for the determination of important structural changes of historic buildings

**Input:**
list of all available layers of structural modifications of the historic building in various stages

**Output:**
Set of significant layers only

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**Workflow of the process**

Collection of accessible data → Data selection and classification → Data preparation → Prediction model → Presentation and next usage of the results
2. Reconstruction of the historical object

- Selection of the historical object
- Materials collection
- Data selection and classification
- Data preparation (reconstruction in MicroStation, geo-referencing in ArcGIS)
- Output in ArcGIS: set of all possible layers in historical periods

Selection of the historical object
Špilberk castle – Brno, Czech republic

Short history: Established under the reign of Přemysl Otakar II, 13th century, then served as seat of Moravian margraves, then was as prison and in the end became a national heritage monument in 1962.
## Materials collection

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</table>
De Rochepine’s plan of Brno city of the year 1749

Example of section of Špilberk castle of 1749
Data selection and classification

- **Historical materials**
  - Text documents
    - Without spatial information
    - With spatial information
- **Graphical documents**
  - Without spatial information
  - With spatial information

**Without spatial information**
- Time-description of the object
- Position and topology of the object

**With spatial information**
- Pictures, photos
- Maps, plans
Data preparation
reconstruction in MicroStation,
geo-referencing in ArcGIS

Archaeological and architectural and historical survey

- Raster and vector data modification (remove redundancy)
- Data selection and evaluation (identical points for geo-referencing, quality of old maps)
- Data completion (geodetic surveying in field)
Data processing

- Planimetric reconstruction (2D)
  - Geo-referencing of historical maps in ArcGIS into S-JTSK system (Datum of Uniform Trigonometric Cadastral Network in the Czech Republic)
  - Data editing and vectorization
  - Stages of construction work determined (new *.shp layers creating)

Data processing

- Altimetry reconstruction (3D) – 2 phases
  1. The creation of digital terrain model (DTM) of Špilberk hill
  2. 3D model of historical reconstruction of Špilberk castle and its fortification
     - materials for DTM have been used (1. phase):
       • A plan of Špilberk castle of 1984 (Brno Museum) in the scale 1:1000 with contour lines with 1 – 0,5 m
       • Altimetry of Špilberk in ZABAGED system (Fundamental Base of Geographic Data)
3D model of historical Špilberk castle creation

1. Finding out and drawing approximate position of the section (identical points). Measuring in field (GPS RTK + laser range finder)
2. Marking intersection with current contour of the object (geo-referencing)
3. Profile unification with current condition of the object. Calculate Viennese fathom (1° = 1,896 m), ell (77,8 cm) and inch into metric system
4. Verification of created profile according to contour lines in digital terrain model
Output in ArcGIS
create all possible layers in historical periods

3. Method of prediction

Typology of prediction models (in general)

Stand-points:
1. Temporal (pre- or post-introduction)

2. Methodology (experimental, simulation, inductive, deductive)

3. Technical processing
   - statistic analysis (analysis of time series, regression analysis)
   - artificial intelligence (neural networks, genetic algorithms)
   - GIS

4. Determination/purpose (marketing, finance, economy, medicine, …)
Conception of the prediction model

- Spatial data
- Attribute data
- Base of knowledge
- Initial inputs of the model

The core of the prediction model based on GIS

Verification of outputs

Correction of input values

Users

- convenient
- inconvenient

Outputs

Feedback

Prediction model based on Markov chain

The conditional distribution of any state $X_{n+1}$, given the past states $X_1, X_2, ..., X_n$ and the present state $X_n$, is independent of the past states and depends only on the present state.

$$P[X_{n+1} = j | X_n = i, X_{n-1} = i_{n-1}, ..., X_2 = i_2, X_1 = i_1] = P[X_{n+1} = j | X_n = i] = P_{ij}$$

$$P_{ij} \geq 0, i, j \geq 0; \sum_{j=1}^{\infty} P_{ij} = 1, i = 1, 2, ...$$
Prediction model based on Markov chain

If the process has a finite number of states, which means the state space \( S = \{1, 2, y, i, j, \ldots, s\} \), then the Markov chain model can be defined by the matrix of one-step transition probabilities:

\[
P = \begin{bmatrix}
P_{11} & P_{12} & P_{1s} \\
P_{21} & P_{22} & P_{2s} \\
\vdots & \vdots & \vdots \\
P_{s1} & P_{s2} & P_{ss}
\end{bmatrix}
\]

The initial probability \( P_{ij} \):

\[
P_{ij} = \frac{N_{ij}}{N_i}
\]

\( N_{ij} \) denotes the transition times from state \( i \) to state \( j \) and \( N_i \) denotes the number of random variables \( \{X_n, n=1, 2, \ldots, m\} \) belonging to state \( i \).

\( p_s \) is probability of remaining in the current state

\( p_{i-1} \) is probability of transition to previous state

\( p_{i+1} \) is probability of transition to next state
Prediction model based on Markov chain

Interpretation of states in Markov chain:

Changes in position between objects in neighboring layers in ArcGIS
Procedure scans by window and computes the probability to the differences between position of the object in various periods
Interpretation: changes $\iff$ uncertainty $\iff$ accuracy
Accuracy estimation: approximately 0.4 m
Changes: > 0.5 m in position

4. Set significant development periods of the historical object

<table>
<thead>
<tr>
<th>Main stages of construction work</th>
<th>Used historical maps (year)</th>
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<tbody>
<tr>
<td>1</td>
<td>1658</td>
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<td>2</td>
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<td>6</td>
<td>1742 – 1759</td>
</tr>
<tr>
<td>7</td>
<td>1759 – 1772</td>
</tr>
</tbody>
</table>
5. Outputs, presentations

- Historical wireframe model of Špilberk castle
- Stages of Špilberk castle construction work, TIN base
- 3D model of Špilberk castle of 1759 in Sketch-Up program
Stages of Špilberk castle construction work, TIN base

3D model of Špilberk castle of 1759 in Sketch-Up program
Conclusions

• Creation of 3D model today non-existing baroque fortification of Špilberk castle (will be improved)
• It will be historically the first 3D digital model of the citadel taking original shape the one in the second half of 18th century (baroque)
• Significance both for specialists and general public

Thank you for your attention