Historical Spatio-temporal data in current GIS

Case Study: German-Herero war of resistance 1904

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Content

• Introduction
• Research Objectives & Questions
• Research Workflow
• Materials & Methodologies
• Evaluation
• Conclusions & Recommendations
History describes geography in the past.

Without time we cannot discuss the past, present nor future.

Spatial data represents features and objects in space at a point in time.

**Problem Definition**

- Need for temporal GIS applications
- Time is hardly supported in GIS applications
- Historical spatio-temporal data is widely available
Case Study Background:

• 1880s German Settlers arrived in SWA.
• Spread Across the country
• Early 1900’s the resistance struggle began.
• Hereros revolted in 1904.
• Germany responded by sending approx. 15000 troops under General Von Trotha.
• Herero got defeated on the 11th August 1904 in a decisive battle of Hamakari.

Source: Resistance struggle 1904 by Klaus Dierks
Research Objectives:

• Framework to automatically extract historical spatio-temporal information from text documents.

• Assess ArcGIS capability in handling time.
**Research Questions:**

1. What methods are available to recognise and extract spatial and temporal information from text documents?

2. How can we extract location event information and produce trajectories from the extracted references?

3. How can historical data be modelled best in regards to
   - Temporal vs. spatial data
   - Precision vs. accuracy of historical information

4. What analysis methods and functions are available for historical spatio-temporal data?

5. What cartographic visualization techniques are suitable to visualize the case study information?
**Data collection**
- Historical documents
- Battle events

**Literature**
- IE
- ST in GIS

**Information Extraction**
- Location visit events
- Moving trajectories

**Visualizing**
- 2D
- 3D
- Time animations
- Story Map

**Analyzing**
- Spatio-temporal analysis
- Trajectory analysis

**Modelling**
- Point in time
- Moving points
- Time queries

**Evaluation**
- IE methods
- Tools and functions
- Uncertainties
**Materials used:**

**Historical publications**

1. Let us die fighting
2. The revolt of the Hereros
3. Chronology of the Namibian history
4. South West Africa under German rule
5. Herero Uprising – Namibia 1 on 1 – online article
6. Battle events – the-eis system

**Tools:**

- Notepad ++
- GATE 8.4
- PostgreSQL 1.6
- ArcGIS 10.5
- Esri Story Map Journal
  - JAPE
  - Python 3.4
Document Pre-processing:

- PDF to XML conversion
11.01. Samuel Maharero orders all Ovaherero chiefs to take up arms against the Germans. He orders them to "refrain from touching missionaries, English, Basters, Berg-Damara, Namas and Boers".

There are doubts concerning the date of this order. It is possible that Maharero wrote this letter after the outbreak of the war (around 20.01.), after the first shots were fired. Maharero tries to involve the Basters, under Hermanus van Wyk and Hendrik Witbooi, in the struggle. The two letters Van Wyk hands over the letters for Witbooi to the Germans. In the second of these letters Samuel writes: "All our obedience to you, my Brother, not to hold aloof from the uprising, but to make your voice heard so that all Africa may hear the voice of the Germans."

Hence I appeal to you, my Brother, not to hold aloof from the uprising, but to make your voice heard so that all Africa may hear the voice of the Germans. The three letters were also written after the outbreak of the war. They can therefore, together with Samuel Maharero's appeal of 12.01. to the German side...

On the other hand, from the very beginning of the German presence in SWA, substantial numbers of Ovaherero are employed by the Germans. The outbreak of the war a number of Ovaherero continue to serve in the German forces.

Some are even killed on the German side.

Gustav Duft tries to negotiate with Samuel Maharero at Okahandja, to no avail because Maharero and Assa Riara are at Osonobe.

12.01. After the first shots were fired at Okahandja (allegedly by the Germans), the Ovaherero revolt throughout SWA.

In the first couple of days 123 Germans are killed (among them 13 active soldiers, seven Boers and five women), goods and livestock are looted, and the German native reserves policy is overthrown.

Missionary Carl Wanderes reports Gustav Duft saying: "If Zurn had not been in Okahandja, then the issue would not have developed so quickly.

Zurn is later threatened with a German court martial because he is held responsible for the outbreak of the war.

A further war cause is the absence of Maharero, Assa Riara and Lentwein from Okahandja.

The many rumours amongst German settlers and soldiers of a possible Ovaherero uprising add to the outbreak of the war, albeit in a disorganised manner.

On 06.01. Kurt Streitwolf reports on a meeting with Trancott Tjetjo in the Gobabis district.

Streitwolf does not believe that war is imminent.

At the Waterberg, Sergeant G Rademacher and missionary Wilhelm Eich react to reports by Else Sonnenberg, whose husband, the German police officer, had been killed.

Rademacher and Eich report that war is unlikely, but that Kambazendi is preparing for a visit of Chief Ovandja at Otjikuru.

The Gobabis-Dama support the Ovaherero.

The Germans are supported by Hendrik Witbooi, but in October 1904 Witbooi is prompted to revolt against German rule by the reinforcement of soldiers from Germany is slow.

Ultimately 14,000 German soldiers are involved, 1,500 of whom die.

This war effort costs Germany 505 million Mark. The uprising is finally suppressed.
Creation of Gazetteers

Temporal gazetteer

<table>
<thead>
<tr>
<th>No.</th>
<th>Entity</th>
<th>Pattern</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>Date</td>
<td>June 1904</td>
</tr>
<tr>
<td>2.</td>
<td>Date</td>
<td>June 13</td>
</tr>
<tr>
<td>3.</td>
<td>Date</td>
<td>June 13, 1904</td>
</tr>
<tr>
<td>4.</td>
<td>Date</td>
<td>13 June</td>
</tr>
<tr>
<td>5.</td>
<td>Date</td>
<td>13 June 1904</td>
</tr>
<tr>
<td>6.</td>
<td>Date</td>
<td>11.06</td>
</tr>
<tr>
<td>7.</td>
<td>Date</td>
<td>11.06.1904</td>
</tr>
</tbody>
</table>

Spatial gazetteer

- List of place names – 3859 place names
-Declared in list.def
Creation of Gazetteers

JAPE Transducer

- Text Patterns
- LHS Rule
- RHS Rule
- Annotation Class

```
Phase: datetimelfinder
Input: Token Lookup SpaceToken
Options: control = applet

//Initialization of regular expressions
Macro: DAY_ONE
  ((Token.kind == number,Token.category==CD, Token.length == "1")
Macro: DAY_TWO
  ((Token.kind == number,Token.category==CD, Token.length == "2")
Macro: YEAR
  ((Token.kind == number,Token.category==CD, Token.length == "4")
Macro: MONTH
  ((Lookup.minorType=="month")

//For date format 12.08 for 12 August
Rule: numberdate
Priority: 50
  (DAY_ONE|DAY_TWO)
  (Token.string == ","| (Token.string == "."| (Token.string == ":")
  (DAY_ONE|DAY_TWO)
  (Token.string == ","| (Token.string == "."| (Token.string == ":")?
  :numberdate
  --> :numberdate.NumberDate= (rule = "numberdate")
```
Contextual Information Extraction

1. NAMED ENTITY EXTRACTION PIPELINE

- Gazetteer Matching
  - Named Entities
    - Person Names
    - Place Names

- JAPE Transducer
  - JAPE Rules
    - Temporal Entities

- Text Processing
  - Tokenizer
  - Splitter
  - POS

2. SPATIO-TEMPORAL RELATIONSHIP EXTRACTION

- Spatial Relationships
- JAPE Rules
- Temporal Relationships
**Introduction**

**Research Objectives & Questions**

**Research Workflow**

**Materials & Methodology**

**Evaluation**

**Conclusions & Recommendations**

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**Entity Extraction Pipeline**

**Text Processing**
- **Tokenizer**
- **Splitter**
- **POS**

**Gazetteer Matching**
- **Named Entities**
  - Person names
  - Place names

**JAPE Transducer**
- **JAPE Rules**
  - Temporal Entities

---

**Date**
- 28./29.03: Zeraua leaves the area of Oruware and moves via Teufelsbach to the east.
- 30.03: Zeraua joins the Otjimbingwe and Omaruru Ovaherero at Samuel’s station at Ongandjira in the upper Swakop valley.

**Person**
- 01.04: Von Glasenapp’s unit proceeds in the direction of Otjikuoko without meeting the Tjetjo community.

**Location**
- 03.04: Tietjo meets the Germans in a battle at a site between Okahuru and Otjikuaro, with heavy losses on both sides.
GATE Annotation Results:

He orders them to refrain from touching missionaries, English, Basters, Berg-Damara, Namas and Boers.

It is possible that Maharero wrote this letter after the outbreak of the war (around 20.01). It is not clear at all, who actually fired these first shots (Missionary Diehl reports that only the Germans fired on his house, not the Ovaherero).
Information Extraction Algorithm:

**Input:** XML Document D, Paragraph P, Sentence E  
**Results:** combine\(T, S, N\)  
where \(T =\) Temporal term, \(S =\) Spatial term, \(N =\) personNames

**Begin:**  
Parse \(D\),  
For each Paragraph \(P\) in \(D\) do:  
Get paragraph date as \(P_d\)  
For each Sentence \(E\) in \(P\) do:  
If only \(S\) and \(N\) then  
assign \(P_d\) as \(T\)  
combine \((T, S, N)\)  
If only one \(T\), one \(S\) and \(N\) then  
combine\((T, S, N)\)  
If multiple \(T\) and one \(S\) then  
assign \(S\) to each \(T\), combine\((T_1, S, N)\), combine\((T_2, S, N)\)....  
If multiple \(S\) and one \(T\) then  
assign \(T\) to each \(S\), combine\((T, S_1, N)\), combine\((T, S_2, N)\)....  
If multiple \(S\) and multiple \(T\) and one \(N\) then:  
if \(S == T\) then  
combine\((T_1, S_1, N)\), combine\((T_2, S_2, N)\)....  
If multiple \(T\), multiple \(S\) and multiple \(N\) then  
if \(T == S == N\) then  
combine\((T_1, S_1, N_1)\), combine\((T_2, S_2, N_2)\)....  
Else  
Jump to next sentence  
Return combine\((T, S, N)\)  
**End**
Extracted information in PostgreSQL:

<table>
<thead>
<tr>
<th>id</th>
<th>person text</th>
<th>location text</th>
<th>date text</th>
<th>temporalrelation text</th>
<th>spatialrelation text</th>
<th>sentenceid integer</th>
</tr>
</thead>
<tbody>
<tr>
<td>97</td>
<td>Tjotjo</td>
<td>between Otjikuwa</td>
<td>03.04.1904</td>
<td></td>
<td>between Otjikuwa</td>
<td>3201</td>
</tr>
<tr>
<td>98</td>
<td>the Germans</td>
<td>between Otjikuwa</td>
<td>03.04.1904</td>
<td></td>
<td>between Otjikuwa</td>
<td>3201</td>
</tr>
<tr>
<td>99</td>
<td>Samuel Mahararo</td>
<td>Okatumba</td>
<td>10.04.1904</td>
<td></td>
<td></td>
<td>3401</td>
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<tr>
<td>100</td>
<td>Samuel Mahararo</td>
<td>Oviombo</td>
<td>10.04.1904</td>
<td></td>
<td></td>
<td>3401</td>
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<td>101</td>
<td>the Germans, Leutwein, Ovaherero</td>
<td>Oviombo</td>
<td>13.04.1904</td>
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<td></td>
<td>3501</td>
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<tr>
<td>102</td>
<td>the Germans, Leutwein, Ovaherero</td>
<td>Otjosaanza</td>
<td>13.04.1904</td>
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<td></td>
<td>3501</td>
</tr>
<tr>
<td>103</td>
<td>Von Glasenappâ</td>
<td>Otjihangwe</td>
<td>24.04.1904</td>
<td></td>
<td></td>
<td>3502</td>
</tr>
<tr>
<td>104</td>
<td>Von Glasenappâ</td>
<td>Otjihaenena</td>
<td>24.04.1904</td>
<td></td>
<td></td>
<td>3502</td>
</tr>
<tr>
<td>105</td>
<td>Ovaherero</td>
<td>Waterberg</td>
<td>19.04.1904</td>
<td></td>
<td></td>
<td>3601</td>
</tr>
<tr>
<td>106</td>
<td>the Germans</td>
<td>Engarawau</td>
<td>19.04.1904</td>
<td></td>
<td></td>
<td>3602</td>
</tr>
<tr>
<td>107</td>
<td>Ovaherero</td>
<td>Okangundi</td>
<td>28.04.1904</td>
<td></td>
<td></td>
<td>3701</td>
</tr>
<tr>
<td>108</td>
<td>Arthur Koppel</td>
<td>Warmquelle</td>
<td>20.05.1904</td>
<td></td>
<td>near Nembundu</td>
<td>3901</td>
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<tr>
<td>109</td>
<td>Kutako</td>
<td>Tsumeb</td>
<td>06.06.1904</td>
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<td></td>
<td>4803</td>
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<tr>
<td>110</td>
<td>Herero</td>
<td>Waterberg</td>
<td>10.08.1904</td>
<td></td>
<td></td>
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<tr>
<td>111</td>
<td>Von Estoff</td>
<td>Okoniparam</td>
<td>10.08.1904</td>
<td></td>
<td></td>
<td>5003</td>
</tr>
</tbody>
</table>

- Cleaning
- Geocoding
- Creating individual trajectories
1. Location visit events
2. Individual trajectories
3. Battle events

We are interested in:

- Space and existence in time
- Change in position
- Spatial relationships in time
- Query attributes of spatial objects in time
Modelling historical events in ArcGIS

- Point in time
- Duration in time
- Time as attribute
Spatio-temporal Cluster Analysis

- Isarithmic Method
- Answers “Where”
- Animated to detect cluster patterns
Spatio-temporal Cluster Analysis

- Grouping Analysis Method
- Defines Spatial and temporal neighbours
- Generate Weight matrix tool
- Space time window method
- Insufficient data
Space – time cube Analysis

- (x, y, time) representation
- Count = Size and colour
- Animated to detect space-time patterns

- Answers:
  - “Where”? 
  - “When”? 

Introduction
Research Objectives & Questions
Research Workflow
Materials & Methodology
Evaluation
Conclusions & Recommendations
Trajectory representations & Analysis
Trajectory representations & Analysis

- What space-time analysis?
- Query trajectory attributes
- Duration between locations
Static and Multiple Static Maps

Monthly historical visit events
Time Animations
Evaluation

Information Extraction Method

• Approach used successfully extracted Spatial, temporal and attributive
• Spatio-temporal relationship terms
• Support Domain specific extractions
• Results in document structure
• Flexible framework

X Time consuming
Modelling time

• Time as attribute
• Limited time retrieval functions
• Simple SQL queries

X Topological relationships in time
## Evaluation

<table>
<thead>
<tr>
<th>Spatio-temporal cluster Analysis</th>
<th>Space time cube analysis</th>
</tr>
</thead>
<tbody>
<tr>
<td>✓ Spatio-temporal neighbors</td>
<td>✓ 3D representation of space &amp; time</td>
</tr>
<tr>
<td>X Requires substantial amount of data</td>
<td>✓ “Where &amp; When” answers</td>
</tr>
<tr>
<td>X Not suitable for dynamic discrete data</td>
<td>✓ Interactivity</td>
</tr>
<tr>
<td></td>
<td>X No attributive information</td>
</tr>
<tr>
<td></td>
<td>X Ability of query cube contents</td>
</tr>
</tbody>
</table>
Evaluation

Trajectory Representation

✓ Moving points
✓ Moving line – track lines
✓ Time animation

✗ Inability to query trajectories
✗ Representation on 2D
✗ Unnatural movement representation
**Evaluation**

**Time animations**
- Time slider functionality
- Time settings
- Events at time of existence
- Emphasize change in time
- Time step – temporal range
- Discrete temporal patterns representation

![Layer Properties window with options for time settings and time step]

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**Introduction**

**Research Objectives & Questions**

**Research Workflow**

**Materials & Methodology**

**Evaluation**

**Conclusions & Recommendations**
Uncertainties in historical data

- Positional uncertainties
  - Unknown settlements
  - Approximated locations
  - Uncertain geographic locations

- Temporal uncertainties
  - Specific dates
  - Range of dates
To what extend are the research questions answered?

1. What methods are available to recognise and extract spatial and temporal information from text documents?

2. How to extract location event information and produce trajectories from the extracted references?

3. How can historical data be modelled best in regards to
   • Temporal vs. spatial data
   • Precision vs. accuracy of historical information

4. What analysis methods and functions are available for historical spatio-temporal data?

5. What cartographic visualization techniques are suitable to visualize the case study information?
There is limited support for time in ArcGIS for historical spatio-temporal information.

Therefore, **recommend**:

- Development of time query functions.
- Development of trajectory representation functions.
- Use and development of Spatio-temporal data models.
THANK YOU FOR YOUR ATTENTION!