Time for Text Mining and Information Retrieval

Jannik Strötgen

jannik.stroetgen@mpi-inf.mpg.de

Joint Lecture Series – Saarbrücken – January 11, 2017
Why temporal information?
From: student@uni.de
To: prof@uni.de
Date: January 11, 2017

Subject: meeting

Dear Prof,

I am sorry that I couldn’t make it on Monday. But could we meet this Friday? I don’t care about the time. What about 2 pm?

Thank you and kind regards,
student
From: student@uni.de
To: prof@uni.de
Date: January 11, 2017

Subject: meeting

Dear Prof,

I am sorry that I couldn't make it on Monday. But could we meet this Friday? I don’t care about the time. What about 2 pm?

Thank you and kind regards,
student
From: student@uni.de
To: prof@uni.de
Date: January 11, 2017

Subject: meeting

Dear Prof,

I am sorry that I couldn’t make it on Monday. But could we meet this Friday? I don’t care about the time. What about 2 pm?

Thank you and kind regards,
student
From: student@uni.de
To: prof@uni.de
Date: January 11, 2017
Subject: meeting

Dear Prof,

I am sorry that I couldn’t make it on Monday. But could we meet this Friday? I don’t care about the time. What about 2 pm?

Thank you and kind regards,
student
From: student@uni.de  
To: prof@uni.de  
Date: January 11, 2017  
Subject: meeting  

Dear Prof,

I am sorry that I couldn’t make it on **Monday**. But could we meet **this Friday**? I don’t care about the time. What about **2 pm**?

Thank you and kind regards, 
student
From: student@uni.de
To: prof@uni.de
Date: January 11, 2017
Subject: meeting

Dear Prof,

I am sorry that I couldn’t make it on Monday. But could we meet this Friday? I don’t care about the time. What about 2 pm?

Thank you and kind regards,
student
Time: crucial role in many types of documents

**Greece Makes ‘Good Progress’ in Payment Talks**

Greek Finance Minister Evangelos Venizelos made “good progress” in a second round of talks with the European Union and International Monetary Fund aimed at staving off default, the EU said.

The talks with Greece’s creditors, which follow a technical default in March, were intended to discuss Greece's ability to meet its obligations. The EU statement said a “full mission” will return to Athens to discuss its bailout program. The group will meet the following day to finalize its decision on Greece’s future in the eurozone.

Staying in the euro area is an “irreversible and fundamental national choice,” Venizelos said in a statement issued by his office.

The Greek parliament has passed a series of reforms that will allow it to continue receiving aid from the bailout programs. The country’s debt crisis has sparked fears that it will be unable to pay off its debts.

---

**1979 Operation**

The Afghan invasion was a major event in the Cold War. The operation was carried out by the KGB and GRU, the Soviet intelligence agencies. The operation was planned to prevent the Soviet Union from losing control of the region.

The operation was successful, and the Soviet forces were able to gain control of the country. The operation continued for several months, and the Soviet forces were able to establish a foothold in Afghanistan.

---

**News articles**

**Wikipedia documents**
Time: crucial role in many types of documents

- short messages
- scientific publications
- literary works
Time: important key characteristics

time is **well-defined**:  

- expressions can be **compared** with each other
Time: important key characteristics

time is **well-defined**:  
- expressions can be **compared** with each other

relations as defined in Allen’s interval algebra [Allen, 1983]

- 2000 *before* March 2001
- *equal*
- *during*
- ...
Time: important key characteristics

- **well-defined:**
  - expressions can be compared with each other

- **organized hierarchically:**
  - different granularities

relations as defined in Allen’s interval algebra [Allen, 1983]
- 2000 **before** March 2001
- **equal**
- **during**
- ...
**Time: important key characteristics**

- **time is well-defined:**
  - expressions can be **compared** with each other

- **relations as defined in Allen’s interval algebra** [Allen, 1983]
  - 2000 **before** March 2001
  - **equal**
  - **during**

- **time can be organized hierarchically:**
  - different granularities
Time: important key characteristics

temporal information can be **normalized**:  
- expressions with **same semantics** $\rightarrow$ **same value**
Time: important key characteristics

temporal information can be normalized:
  - expressions with same semantics → same value
Time: important key characteristics

temporal information can be normalized:
- expressions with **same semantics** → **same value**
Why Time? Temporal Tagging HeidelTime Applications Summary

Time: important key characteristics

temporal information can be **normalized**:  
- expressions with **same semantics** → **same value**

Joint Lecture Series – January 11, 2017 © Jannik Strötgen
Time: important key characteristics

temporal information can be **normalized**:
- expressions with **same semantics** → **same value**

Temporal information is **term- and language-independent**
Time: valuable for many applications

- information retrieval (search engines)
- information extraction
Time: valuable for many applications

- information retrieval (search engines)
- information extraction
- text summarization
- machine translation
- question answering
- …
Why Time? Temporal Tagging HeidelTime Applications Summary

Time: valuable for many applications

- information retrieval (search engines)
- information extraction
- text summarization
- machine translation
- question answering
- ...

prerequisite: temporal tagging
Questions addressed in this talk

- Why temporal information?
- What’s temporal tagging?
- Why domain-sensitive temporal tagging?
- What applications can exploit temporal information and how?
Questions addressed in this talk

- Why temporal information?

- What’s temporal tagging?

- Why domain-sensitive temporal tagging?

- What applications can exploit temporal information and how?
The two tasks of a temporal tagger

1. **extraction** of temporal expressions
The two tasks of a temporal tagger

1. **extraction** of temporal expressions

---

**main challenge**

ambiguities, e.g., may, march, fall, 2000
The two tasks of a temporal tagger

1. **extraction** of temporal expressions
The two tasks of a temporal tagger

1. **extraction** of temporal expressions
2. **normalization** of temporal expressions

---

**Greece Makes ‘Good Progress’ in Payment Talks**

By Maria Petrikis and Natalie

Greek Finance Minister Evangelos Venizelos made “good progress” in a second round of talks with the European Union and International Monetary Fund aimed at staving off default, the EU said.

The telephone meetings, which followed earlier talks in Athens aimed to damp concerns that Greece’s debt crisis was spinning out of control and to clear the way for a sixth installment of rescue funds. The EU statement said a “full mission” will return to Athens to discuss the next steps.

Staying in the euro area is an “irreversible and fundamental national choice,” Venizelos said in a statement following the talks.

The statement said that “we need to do more, but we need to tackle once and for all.”

The EU’s return to Greece comes as the country’s finance minister George Papandreou fights to keep the country in the eurozone.

---

- **tonight** → **2011-09-20TNI**
- **yesterday** → **2011-09-19**
- **next week** → **2011-W39**
- **Sept. 20, 2011** → **2011-09-20**
- **next month** → **2011-10**
The two tasks of a temporal tagger

1. **extraction** of temporal expressions
2. **normalization** of temporal expressions

---

**Greece Makes ‘Good Progress’ in Payment Talks**

By Maria Petrakis and Natalie

Sep 20, 2011 10:39 PM GMT+0200

Greek Finance Minister Evangelos Venizelos made “good progress” in a second round of talks with the European Union and International Monetary Fund aimed at staving off default, the EU said.

The telephone meetings, which follow one in June, were intended to damp concerns that Greece will miss targets and to clear the way for a sixth installment of rescue funds. The EU statement said a “full mission” will return to Athens in early October.

Discussions in coming days at the IMF’s annual meeting in Washington.

Staying in the euro area is an “irreversible and fundamental national choice,” Venizelos said in a statement.

The EL has data and economic forecasts to be published, and “need to know that the fiscal data and economic forecasts are accurate for the euro,” he said.

The EL’s payment for Greece is on track to be the one of the largest for a country in the eurozone.

---

**Why Time?**

**Temporal Tagging**

**HeidelTime**

**Applications**

**Summary**
Types of temporal expressions

- **dates**
  - June 2001

- **times**
  - yesterday morning

- **durations**
  - several months

- **sets**
  - every day
Realizations of date expressions

- **explicit** → *easy to normalize*
  - June 24, 2013
  - the 20th century
Realizations of date expressions

- **explicit** → easy to normalize
  - June 24, 2013
  - the 20th century

- **implicit** → additional knowledge required
  - Christmas 2012
  - Columbus Day 2006
Realizations of date expressions

- **explicit** → *easy to normalize*
  - June 24, 2013
  - the 20th century

- **implicit** → *additional knowledge required*
  - Christmas 2012
  - Columbus Day 2006

- **relative** → *reference time required*
  - two weeks later
  - yesterday
Realizations of date expressions

- **explicit** → easy to normalize
  - June 24, 2013
  - the 20th century

- **implicit** → additional knowledge required
  - Christmas 2012
  - Columbus Day 2006

- **relative** → reference time required
  - two weeks later
  - yesterday

- **underspecified** → reference time and relation to it required
  - Monday
  - June 24
Realizations of date expressions

- **explicit** → easy to normalize
  - June 24, 2013
  - the 20th century

- **implicit** → additional knowledge required
  - Christmas 2012
  - Columbus Day 2006

- **relative** → reference time required
  - two weeks later
  - yesterday

- **underspecified** → reference time and relation to it required
  - Monday
  - June 24

often challenging

normalization of relative and underspecified expressions
Temporal tagging example

Document Creation Time: 2000-12-26

... On Thursday, the Census Bureau will publish the official population count for the United States, including the state-by-state totals required under the Constitution to determine how many seats each state is allocated in the House. The figures, eagerly awaited by many state government officials, are the first in a wave of releases of demographic data based on the 2000 census. ... Population estimates issued periodically by the Census Bureau indicate that as of October, 275,843,000 people were living in ... Additional seats are then assigned to each state based on a person-to-House-member ratio that changes every 10 years because the country’s population keeps growing ...
On Thursday, the Census Bureau will publish the official population count for the United States, including the state-by-state totals required under the Constitution to determine how many seats each state is allocated in the House. The figures, eagerly awaited by many state government officials, are the first in a wave of releases of demographic data based on the 2000 census. ... Population estimates issued periodically by the Census Bureau indicate that as of October, 275,843,000 people were living in ... Additional seats are then assigned to each state based on a person-to-House-member ratio that changes every 10 years because the country’s population keeps growing ...
Temporal tagging example

...On Thursday, the Census Bureau will publish the official population count for the United States, including the state-by-state totals required under the Constitution to determine how many seats each state is allocated in the House. The figures, eagerly awaited by many state government officials, are the first in a wave of releases of demographic data based on the 2000 census. ... Population estimates issued periodically by the Census Bureau indicate that as of October, 275,843,000 people were living in ... Additional seats are then assigned to each state based on a person-to-House-member ratio that changes every 10 years because the country’s population keeps growing ...
Temporal tagging example

On **Thursday**, the Census Bureau will publish the official population count for the United States, including the state-by-state totals required under the Constitution to determine how many seats each state is allocated in the House. The figures, eagerly awaited by many state government officials, are the first in a wave of releases of demographic data based on the **2000** census. **...**

Population estimates issued periodically by the Census Bureau indicate that as of **October**, 275,843,000 people were living in **...** Additional seats are then assigned to each state based on a person-to-House-member ratio that changes **every 10 years** because the country’s population keeps growing **...**
... On Thursday, the Census Bureau will publish the official population count for the United States, including the state-by-state totals required under the Constitution to determine how many seats each state is allocated in the House. The figures, eagerly awaited by many state government officials, are the first in a wave of releases of demographic data based on the 2000 census. ... Population estimates issued periodically by the Census Bureau indicate that as of October, 275,843,000 people were living in ... Additional seats are then assigned to each state based on a person-to-House-member ratio that changes every 10 years because the country's population keeps growing ...
Temporal tagging of news(-style) documents

normalization typically with document creation time

Document Creation Time: 2000-12-26

... On Thursday, the Census Bureau will publish the official population count for the United States, including the state-by-state totals required under the Constitution to determine how many seats each state is allocated in the House. The figures, eagerly awaited by many state government officials, are the first in a wave of releases of demographic data based on the 2000 census. ... Population estimates issued periodically by the Census Bureau indicate that as of October, 275,843,000 people were living in ... Additional seats are then assigned to each state based on a person-to-House-member ratio that changes every 10 years because the country’s population keeps growing ...
Questions addressed in this talk

- Why temporal information?
- What’s temporal tagging?
- Why domain-sensitive temporal tagging?
- What applications can exploit temporal information and how?
Temporal tagging of narrative documents

Soviet-Afghan War
1979: Soviet deployment
The Afghan government, having secured a treaty in the spring and summer of 1979. They requested Soviet troops to provide security and to assist in the fight against the mujahideen rebels. On April 14, 1979, the Afghan government requested that the USSR send 15 to 20 helicopters with their crews to Afghanistan, and on June 16... The operation was fully complete by the morning of December 28, 1979. ... According to the Soviet Politburo they were complying with the 1978 Treaty of Friendship, Cooperation and Good Neighborliness... Soviet ground forces, under the command of Marshal Sergei Sokolov, entered Afghanistan from the north on December 27. In the morning, the 103rd Guards...
Temporal tagging of narrative documents

**Soviet-Afghan War**

**1979**: Soviet deployment

The Afghan government, having secured a treaty in the spring and summer of 1979, they requested Soviet troops to provide security and to assist in the fight against the mujahideen rebels. On **April 14, 1979**, the Afghan government requested that the USSR send 15 to 20 helicopters with their crews to Afghanistan, and on **June 16**, the operation was fully complete by **the morning of December 28, 1979**. According to the Soviet Politburo they were complying with the **1978 Treaty of Friendship, Cooperation and Good Neighborliness**. Soviet ground forces, under the command of Marshal Sergei Sokolov, entered Afghanistan from the north on **December 27**, in **the morning**, the 103rd Guards...
Temporal tagging of narrative documents

reference time identification in the text required

Soviet-Afghan War
1979: Soviet deployment

The Afghan government, having secured a treaty in the spring and summer of 1979, they requested Soviet troops to provide security and to assist in the fight against the mujahideen rebels. On April 14, 1979, the Afghan government requested that the USSR send 15 to 20 helicopters with their crews to Afghanistan, and on June 16... The operation was fully complete by the morning of December 28, 1979. According to the Soviet Politburo they were complying with the 1978 Treaty of Friendship, Cooperation and Good Neighborliness... Soviet ground forces, under the command of Marshal Sergei Sokolov, entered Afghanistan from the north on December 27. In the morning, the 103rd Guards...
Temporal tagging of narrative documents

reference time identification in the text required

Soviet-Afghan War

The Afghan government, having secured a treaty in the spring and summer of 1979, they requested Soviet troops to provide security and to assist in the fight against the mujahideen rebels. On April 14, 1979, the Afghan government requested that the USSR send 15 to 20 helicopters with their crews to Afghanistan, and on June 16... The operation was fully complete by the morning of December 28, 1979. According to the Soviet Politburo they were complying with the 1978 Treaty of Friendship, Cooperation and Good Neighborliness... Soviet ground forces, under the command of Marshal Sergei Sokolov, entered Afghanistan from the north on December 27... In the morning, the 103rd Guards...
Temporal tagging of narrative documents

Reference time identification in the text required

Soviet-Afghan War

1979: Soviet deployment

The Afghan government, having secured a treaty in the spring and summer of 1979, requested Soviet troops to provide security and assist in the fight against the mujahideen rebels. On April 14, 1979, the Afghan government requested that the USSR send 15 to 20 helicopters with their crews to Afghanistan, and on June 16, ... The operation was fully complete by the morning of December 28, 1979. ... According to the Soviet Politburo they were complying with the 1978 Treaty of Friendship, Cooperation and Good Neighborliness ... Soviet ground forces, under the command of Marshal Sergei Sokolov, entered Afghanistan from the north on December 27. In the morning, the 103rd Guards ...
Temporal tagging of narrative documents

reference time identification in the text required

Soviet-Afghan War

1979: Soviet deployment
The Afghan government, having secured a treaty in the spring and summer of 1979, requested Soviet troops to provide security and assist in the fight against the mujahideen rebels. On April 14, 1979, the Afghan government requested that the USSR send 15 to 20 helicopters with their crews to Afghanistan, and on June 16, the operation was fully complete by the morning of December 28, 1979. According to the Soviet Politburo, they were complying with the 1978 Treaty of Friendship, Cooperation, and Good Neighborliness. Soviet ground forces, under the command of Marshal Sergei Sokolov, entered Afghanistan from the north on December 27. In the morning, the 103rd Guards...

WikiWars corpus, 18_SovietsInAfghanistan.key.xml
Temporal tagging of colloquial documents

(a) Yo! Rem to come for lab tmr:-) no need bring anything rite?  
Time4SMS corpus, 0019314.key.xml

(b) Whats it u wanted 2 say last nite? Did anna contact u? 
Time4SMS corpus, 0027197.key.xml

(c) Dear people, andy ng is availableat 10 am in his office.  
Time4SMS corpus, 0024336.key.xml

(d) Meet sunshine place on Thurs? 
Time4SMS corpus, 0019442.key.xml
Temporal tagging of colloquial documents

(a) Yo! Rem to come for lab tmr :-) no need bring anything rite? 2010-09-23
Time4SMS corpus, 0019314.key.xml

(b) What's it u wanted 2 say last nite? Did anna contact u? 2010-01-10
Time4SMS corpus, 0027197.key.xml

(c) Dear people, andy ng is available at 10 am in his office. 2011-02-16T12:42
Time4SMS corpus, 0024336.key.xml

(d) Meet sunshine place on Thurs? 2010-10-05
Time4SMS corpus, 0019442.key.xml
Temporal tagging of colloquial documents

(a) Yo! Rem to come for lab - (tmr :- ) no need bring anything rite? 2010-09-23
   Time4SMS corpus, 0019314.key.xml

(b) What's it u wanted 2 say - (last nite ? Did anna contact u? 2010-01-10
   Time4SMS corpus, 0027197.key.xml

(c) Dear people, andy ng is available at 10 am in his office. 2011-02-16T12:42
   Time4SMS corpus, 0024336.key.xml

(d) Meet sunshine place on Thurs ? 2010-10-05
   Time4SMS corpus, 0019442.key.xml
Temporal tagging of colloquial documents

noisy language and missing context information

(a) Yo! Rem to come for lab tmr :-) no need bring anything rite? 2010-09-23
Time4SMS corpus, 0019314.key.xml

(b) Whats it u wanted 2 say last nite? Did anna contact u? 2010-01-10
Time4SMS corpus, 0027197.key.xml

(c) Dear people, andy ng is availableat 10 am in his office. 2011-02-16T12:42
Time4SMS corpus, 0024336.key.xml

(d) Meet sunshine place on Thurs ? 2010-10-05
Time4SMS corpus, 0019442.key.xml
Temporal tagging of scientific documents

**Supplementation with all three macular carotenoids**

Subjects consumed one tablet per day containing 10.6 mg MZ, 5.9 mg L and 1.2 mg Z (Intervention, I group) or placebo (P group). . . . Subjects were assessed at baseline, two and four months. Clinical pathology analysis was performed at baseline and four months.
Temporal tagging of scientific documents

Supplementation with all three macular carotenoids

Subjects consumed one tablet per day containing 10.6 mg MZ, 5.9 mg L and 1.2 mg Z (Intervention, I group) or placebo (P group). ... Subjects were assessed at baseline, two and four months. Clinical pathology analysis was performed at baseline and four months.

Time4SCI corpus, 21979997.key.xml
Temporal tagging of scientific documents

no real points in time, but local time frame

Supplementation with all three macular carotenoids

Subjects consumed one tablet per day containing 10.6 mg MZ, 5.9 mg L and 1.2 mg Z (Intervention, I group) or placebo (P group). ... Subjects were assessed at baseline, two, and four months. Clinical pathology analysis was performed at baseline and four months.

Time4SCI corpus, 21979997.key.xml
Why domain-sensitive temporal tagging?

domain

- group of documents with
- same characteristics relevant for temporal tagging

---

Joint Lecture Series – January 11, 2017

© Jannik Strötgen 19 / 50
Why domain-sensitive temporal tagging?

**domain**

group of documents with

**same characteristics relevant for temporal tagging**

**news**

- news articles
- letters
- formal emails
Why domain-sensitive temporal tagging?

domain

- group of documents with same characteristics relevant for temporal tagging

news
- news articles
- letters
- formal emails

narrative
- Wikipedia
- descriptive documents
Why domain-sensitive temporal tagging?

<table>
<thead>
<tr>
<th>Domain</th>
<th>Group of Documents with Same Characteristics Relevant for Temporal Tagging</th>
</tr>
</thead>
<tbody>
<tr>
<td>News</td>
<td>- news articles&lt;br&gt;- letters&lt;br&gt;- formal emails</td>
</tr>
<tr>
<td>Narrative</td>
<td>- Wikipedia&lt;br&gt;- descriptive documents</td>
</tr>
<tr>
<td>Colloquial</td>
<td>- SMS&lt;br&gt;- tweets&lt;br&gt;- user-g. content</td>
</tr>
</tbody>
</table>
Why domain-sensitive temporal tagging?

domain

- group of documents with same characteristics relevant for temporal tagging

**news**
- news articles
- letters
- formal emails

**narrative**
- Wikipedia
- descriptive documents

**colloquial**
- SMS
- tweets
- user-g. content

**autonomic**
- scientific documents
- literary works
Why domain-sensitive temporal tagging?

domain

- group of documents with same characteristics relevant for temporal tagging

news
- news articles
- letters
- formal emails

narrative
- Wikipedia
- descriptive documents

colloquial
- SMS
- tweets
- user-g. content

autonomic
- scientific documents
- literary works

differences between documents of different domains
- normalization of relative and underspecified expressions
- type of language (formal, scientific, historic, colloquial)
Why domain-sensitive temporal tagging?

**domain**

group of documents with same characteristics relevant for temporal tagging

---

**news**
- news articles
- letters
- formal emails

**narrative**
- Wikipedia
- descriptive documents

**colloquial**
- SMS
- tweets
- user-g. content

**autonomic**
- scientific documents
- literary works

---

**differences between** documents of different domains

- normalization of relative and underspecified expressions
- type of language (formal, scientific, historic, colloquial)
- different types of temporal expressions
Why domain-sensitive temporal tagging?

**corpus comparison**

with manually annotated corpora of four domains
Why domain-sensitive temporal tagging?

corpus comparison

with manually annotated corpora of four domains

![Graph showing occurrences of different temporal elements in news and narrative corpora.]
Why domain-sensitive temporal tagging?

corpus comparison
with manually annotated corpora of four domains

news
narrative
colloquial

Occurrences [%]

Date  Time  Duration  Set

Joint Lecture Series – January 11, 2017
Why domain-sensitive temporal tagging?

corpus comparison
with manually annotated corpora of four domains

Joint Lecture Series – January 11, 2017

© Jannik Strötgen
State-of-the-art in temporal tagging 2010

some research on temporal tagging

- annotation standards (e.g., TimeML [Pustejovsky et al. (2005)])
State-of-the-art in temporal tagging 2010

some research on temporal tagging

- annotation standards (e.g., TimeML [Pustejovsky et al. (2005)])

- temporal taggers
  - only few available (e.g., GUTime [Verhagen & Pustejovsky (2008)])
  - if available, **hardly extensible**
  - focus on **English**
  - research only on **news documents**
State-of-the-art in temporal tagging 2010

some research on temporal tagging

- annotation standards (e.g., TimeML [Pustejovsky et al. (2005)])
- temporal taggers
  - only few available (e.g., GUTime [Verhagen & Pustejovsky (2008)])
  - if available, **hardly extensible**
  - focus on **English**
  - research only on **news documents**

there was a need for a domain-sensitive temporal tagger
Domain-sensitive normalization strategies
Remember: domain-sensitive normalization

Temporal tagging of news(-style) documents

**Document Creation Time:** 2000-12-26

...On **Thursday**, the Census Bureau will publish the official population count for the United States, including the state-by-state totals required under the Constitution to determine how many seats each state is allocated in the House. The figures, eagerly awaited by many state government officials, are the first in a wave of releases of demographic data based on the **2000 census**. ...Population estimates issued periodically by the Census Bureau indicate that as of **October**, 275,843,000 people were living in ...Additional seats are then assigned to each state based on a person-to-House-member ratio that changes **every 10 years** because the country’s population keeps growing ...

Temporal tagging of colloquial documents

noisy language and missing context information

(a) **Yo! Rem to come for lab tmr :-) no need bring anything rite?** 2010-09-23
(b) **Whats it u wanted 2 say last nite? Did anna contact u?** 2010-01-10
(c) **Dear people, andy ng is availableat 10 am in his office**. 2011-02-16T12:42
(d) **Meet sunshine place on Thurs**. 2010-10-05

Temporal tagging of scientific documents

**Supplementation with all three macular carotenoids**

Subjects consumed one tablet per day containing 10.6 mg MZ, 5.9 mg L and 1.2 mg Z (Intervention, I group) or placebo (P group). ...Subjects were as-

**Temporal tagging of narrative documents**

reference time identification in the text required

**Soviet-Afghan War**

**1979** Soviet deployment

The Afghan government, having secured a treaty in the spring, ... Soviet ground forces, under the command of Marshal Sergei Sokolov, entered Afghanistan from the north on **December 27**. In the morning, the 103rd Guards...

On **April 14, 1979**, the Afghan government requested that the USSR send 15 to 20 helicopters with their crews to Afghanistan, and on **June 16** ... The operation was fully complete by **the morning of December 28, 1979**. ... According to the Soviet Politburo they were complying with the **1978 Treaty of Friendship, Cooperation and Good Neighborliness** ...

**2017-01-10**
Domain-sensitive normalization strategies

reference time detection for underspecified expressions

underspecified
(e.g., “December”)
Domain-sensitive normalization strategies

reference time detection for underspecified expressions

underspecified
(e.g., “December”)

news, colloquial

DCT
Domain-sensitive normalization strategies

reference time detection for underspecified expressions

- underspecified (e.g., “December”)
  - news, colloquial
  - narrative
    - previously mentioned expression
  - DCT

Joint Lecture Series – January 11, 2017 © Jannik Strötgen
Domain-sensitive normalization strategies

reference time detection for underspecified expressions

- underspecified (e.g., “December”)
  - news, colloquial
    - DCT
  - narrative
  - autonomic
    - previously mentioned expression
    - local time frame (previous expression or new TPZ)
Domain-sensitive normalization strategies

- Reference time detection for relative expressions

- Context-independent (e.g., “today”)
  - News, colloquial
  - DCT

- Context-dependent (e.g., “the following day”)
  - Narrative
  - Autonomic
    - Local time frame (previous expression or new TPZ)
    - News, colloquial, narrative
      - Previously mentioned expression
Domain-sensitive normalization strategies

relation between underspecified expression and reference time

underspecified
(e.g., “December”)

Joint Lecture Series – January 11, 2017
© Jannik Strötgen
Domain-sensitive normalization strategies

relation between underspecified expression and reference time

underspecified
(e.g., “December”)

news, colloquial
(ref=DCT)

no tense

news, colloquial
(past)

before, after

before, present

after

narrative
(ref ≠ DCT)

after

autonomic
(local time frame)

after

(if not new TPZ)
Domain-sensitive normalization strategies

relation between underspecified expression and reference time

underspecified (e.g., “December”)

news, colloquial
(ref=DCT)

no tense  past

news  colloquial

before  after  before
Domain-sensitive normalization strategies

relation between underspecified expression and reference time

underspecified (e.g., “December”)

news, colloquial
(ref=DCT)

no tense

news colloquial

past

present / future

before after before

after
Domain-sensitive normalization strategies

relation between underspecified expression and reference time

undespecified (e.g., “December”)

news, colloquial (ref=DCT)

news, colloquial

no tense

past

news, colloquial

present / future

narrative (ref≠DCT)

before

after

before

after

after

after

autonomic (local time frame)

after (if not new TPZ)
Domain-sensitive normalization strategies

relation between underspecified expression and reference time

- *news, colloquial* (ref=DCT)
  - no tense
  - past
  - *news* colloquial
  - before after before

- *narrative* (ref≠DCT)
  - present future
  - after after

- *autonomic* (local time frame)
  - after
  - (if not new TPZ)
The temporal tagger HeidelTime

[SemEval’10,’13, LREC’12,’14, LRE’13]
[EVALITA’14, EACL’14, TALIP’14, EMNLP’15]

characteristics

- rule-based, multilingual, domain-sensitive
The temporal tagger HeidelTime

[SemEval’10,’13, LREC’12,’14, LRE’13]  
[EVALITA’14, EACL’14, TALIP’14, EMNLP’15]

characteristics

- rule-based, multilingual, domain-sensitive

extraction

- based on regular expressions
- linguistic features (POS, POS of next token, ...)
- knowledge resources (names of months, holidays, ...)
The temporal tagger HeidelTime

characteristics
- rule-based, multilingual, domain-sensitive

extraction
- based on regular expressions
- linguistic features (POS, POS of next token, ...)
- knowledge resources (names of months, holidays, ...)

normalization
- linguistic clues (tense in sentence, ...)
- domain-specific normalization strategies
The temporal tagger HeidelTime

4 domains: news, narrative, colloquial, autonomic

13 languages
- manually created resources
- some added by colleagues, some by other researchers
The temporal tagger HeidelTime

**4 domains:** news, narrative, colloquial, autonomic

**13 languages**
- manually created resources
- some added by colleagues, some by other researchers

[Moriceau & Tannier (2014),
Camp & Christiansen (2012),
Skukan et al. (2014)]

easy to extend to further languages
The temporal tagger HeidelTime

4 domains: news, narrative, colloquial, autonomic

13 languages
- manually created resources
- some added by colleagues, some by other researchers

Ayser
Armiti

Hui Li

Canh
Van Tran

[Morieau & Tannier (2014),
Camp & Christiansen (2012),
Skukan et al. (2014)]

easy to extend to further languages
The temporal tagger HeidelTime

4 **domains**: news, narrative, colloquial, autonomic

13 **languages**
- manually created resources
- some added by colleagues, some by other researchers

200 **languages**
- automatically created resources [EMNLP’15]
The temporal tagger HeidelTime

4 domains: news, narrative, colloquial, autonomic

13 languages
- manually created resources
- some added by colleagues, some by other researchers

200 languages
- automatically created resources [EMNLP’15]

publicly available (UIMA, GATE, Java standalone, online demo)
- quite widely used
- first domain-sensitive temporal tagger
- only tagger for some of the languages
HeidelTime – extensive evaluation

state-of-the-art system for extraction & normalization

- on all publicly available corpora
- for (almost) all languages and domains
HeidelTime – extensive evaluation

state-of-the-art system for extraction & normalization

- on all publicly available corpora
- for (almost) all languages and domains
- **winner of research competitions**
  - TempEval-2 (en), TempEval-3 (en, sp), Evalita’14 (it)
  [Verhagen et al. (2010), UzZaman et al. (2010), Caselli et al. (2014)]
HeidelTime – extensive evaluation

state-of-the-art system for extraction & normalization

- on all publicly available corpora
- for (almost) all languages and domains
- winner of research competitions
  - TempEval-2 (en), TempEval-3 (en, sp), Evalita’14 (it)
    [Verhagen et al. (2010), UzZaman et al. (2010), Caselli et al. (2014)]
- no detailed numbers, but . . .
Value of HeidelTime’s domain-sensitive strategies

cross-domain evaluation

<table>
<thead>
<tr>
<th>corpus</th>
<th>strategy</th>
<th>extraction</th>
<th>normalization</th>
</tr>
</thead>
<tbody>
<tr>
<td>news</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>narrative</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Value of HeidelTime’s domain-sensitive strategies

cross-domain evaluation

<table>
<thead>
<tr>
<th>corpus</th>
<th>strategy</th>
<th>extraction</th>
<th>normalization</th>
</tr>
</thead>
<tbody>
<tr>
<td>news</td>
<td>news</td>
<td>91.1</td>
<td>78.6</td>
</tr>
<tr>
<td>narrative</td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
Value of HeidelTime’s domain-sensitive strategies

cross-domain evaluation

<table>
<thead>
<tr>
<th>corpus</th>
<th>strategy</th>
<th>extraction</th>
<th>normalization</th>
</tr>
</thead>
<tbody>
<tr>
<td>news</td>
<td>news</td>
<td>91.1</td>
<td>78.6</td>
</tr>
<tr>
<td>narrative</td>
<td>news</td>
<td>87.9</td>
<td>56.9</td>
</tr>
</tbody>
</table>
Value of HeidelTime’s domain-sensitive strategies

cross-domain evaluation

<table>
<thead>
<tr>
<th>corpus</th>
<th>strategy</th>
<th>extraction</th>
<th>normalization</th>
</tr>
</thead>
<tbody>
<tr>
<td>news</td>
<td>news</td>
<td>91.1</td>
<td>78.6</td>
</tr>
<tr>
<td>narrative</td>
<td>news</td>
<td>87.9</td>
<td>56.9</td>
</tr>
<tr>
<td></td>
<td>narratives</td>
<td>87.9</td>
<td>78.7</td>
</tr>
</tbody>
</table>

Don’t trust a tagger developed for news if you want to process narratives (e.g., Wikipedia). Some details to explain the “200 languages extension.”
Value of HeidelTime’s domain-sensitive strategies

cross-domain evaluation

<table>
<thead>
<tr>
<th>corpus</th>
<th>strategy</th>
<th>extraction</th>
<th>normalization</th>
</tr>
</thead>
<tbody>
<tr>
<td>news</td>
<td>news</td>
<td>91.1</td>
<td>78.6</td>
</tr>
<tr>
<td></td>
<td>narratives</td>
<td>91.1</td>
<td>61.5</td>
</tr>
<tr>
<td>narrative</td>
<td>news</td>
<td>87.9</td>
<td>56.9</td>
</tr>
<tr>
<td></td>
<td>narratives</td>
<td>87.9</td>
<td>78.7</td>
</tr>
</tbody>
</table>

Don’t trust a tagger developed for news if you want to process narratives (e.g., Wikipedia)
Value of HeidelTime’s domain-sensitive strategies

cross-domain evaluation

<table>
<thead>
<tr>
<th>corpus</th>
<th>strategy</th>
<th>extraction</th>
<th>normalization</th>
</tr>
</thead>
<tbody>
<tr>
<td>news</td>
<td>news</td>
<td>91.1</td>
<td>78.6</td>
</tr>
<tr>
<td></td>
<td>narratives</td>
<td>91.1</td>
<td>61.5</td>
</tr>
<tr>
<td>narrative</td>
<td>news</td>
<td>87.9</td>
<td>56.9</td>
</tr>
<tr>
<td></td>
<td>narratives</td>
<td>87.9</td>
<td>78.7</td>
</tr>
</tbody>
</table>

Don’t trust a tagger developed for news if you want to process narratives (e.g., Wikipedia)

now: some details to explain the “200 languages extension”
HeidelTime’s architecture

- patterns
- normalization knowledge
- rules
→ language-dependent
HeidelTime’s architecture

- patterns
- normalization knowledge
- rules
  → language-dependent

well-defined rule syntax (outside of source code)
HeidelTime’s architecture

- domain-specific normalization strategies
- resource interpreter
  → language-independent

- patterns
- normalization knowledge
- rules
  → language-dependent

well-defined rule syntax (outside of source code)
HeidelTime’s language resources

Pattern files:
- frequently used terms

// Pattern resource
// for
// month names
// reMonthName
January
February
March
...

// Pattern resource
// for
// month abbrev.
// reMonthShort
Jan\.?
Feb\.?
Mar\.?
....

// Pattern resource
// for
// month numbers
// reMonthNumber
10
11
12
0?[1–9]
HeidelTime’s language resources

Pattern files:
- frequently used terms

Normalization files:
- contain normalized values of such terms
HeidelTime’s language resources

After read by HeidelTime, accessible by rules:

- `reMonthLong = (January|February|...)`
- `reMonthShort = (Jan.?|Feb.?|Mar.?|...)`
- `reMonthNumber = (10|11|12|0?[1-9])`
- `normMonth(January) = 01`
- `normMonth(Jan) = 01`
- `normMonth(1) = 01`

Rule files:
- every rule contains at least:
  - rule name
  - extraction part – calls pattern
  - value normalization part – calls normalization functions
Temporal tagging of 200 languages [EMNLP’15]

so far: for 13 languages

- manual resource development for each added language
Temporal tagging of 200 languages [EMNLP’15]

so far: for 13 languages

- manual resource development for each added language

disadvantages:

- labor and time intensive
- language knowledge required
- there are many more languages not yet addressed
Temporal tagging of 200 languages [EMNLP’15]

so far: for 13 languages
- manual resource development for each added language

disadvantages:
- labor and time intensive
- language knowledge required
- there are many more languages not yet addressed

developing language resources automatically
- simplified English resources as starting point for translations
- resource development process for “all languages”
- language-independent rules
Developing language resources automatically

resource development process for “all languages”

Simplified English resources

normMonthLong
"January","01"
"February","02"
...
Developing language resources automatically

resource development process for “all languages”

Simplified English resources

```
// spanish
// reMonthLong
```
```
// spanish
// normMonthLong
```
```
// german
// reMonthLong
```
```
// german
// normMonthLong
```
Developing language resources automatically

resource development process for “all languages”
Developing language resources automatically

resource development process for “all languages”

Simplified English resources

```
// spanish
// reMonthLong

January translations = {
    german: Januar,
    spanish: enero
}
```

for each language

Wiktionary

```
// normMonthLong

''January'',''01''
''February'',''02''
...
```

extract patterns

Joint Lecture Series – January 11, 2017
Developing language resources automatically

resource development process for “all languages”

Simplified English resources

```plaintext
// normMonthLong
"January","01" 
"February","02"
...
```

extract patterns

```
input
January
February
...
```

for each language

```
// spanish
// reMonthLong
// "January","01"
enero
// "February","02"
febrero
```

add patterns

```
// german
// reMonthLong
// "January","01"
Januar
// "February","02"
Februar
```

add normalizations

```
// spanish
// normMonthLong
// "January","01"
enero","01"
// "February","02"
```

```
// german
// normMonthLong
// "January","01"
Januar","01"
// "February","02"
```

```
January
translations = {
    german: Januar
    spanish: enero
...
}
```

Wiktionary
Developing language resources automatically

**language-independent rules** (based on English rules)
- no language-dependent words
- add “creative rules”, e.g., permutations of patterns
Developing language resources automatically

**language-independent rules** (based on English rules)
- no language-dependent words
- add “creative rules”, e.g., permutations of patterns

**assumption**
- obviously, not all rules required for all languages
  - but: “unnecessary” rules are unlikely to harm results
Developing language resources automatically

**language-independent rules** (based on English rules)
- no language-dependent words
- add “creative rules”, e.g., permutations of patterns

**assumption**
- obviously, not all rules required for all languages
  - but: “unnecessary” rules are unlikely to harm results

**evaluation**
- very promising
- baseline for most of the 200 languages
Questions addressed in this talk

- Why temporal information?
- What’s temporal tagging?
- Why domain-sensitive temporal tagging?
- What applications can exploit temporal information and how?
The email-calendar application

From: student@uni.de
To: prof@uni.de
Date: January 11, 2017

Subject: meeting

Dear Prof,

I am sorry that I couldn’t make it on **Monday**. But could we meet **this Friday**? I don’t care about the time. What about **2 pm**?

Thank you and kind regards,

student
Time for search engines

temporal information needs are frequent

query log analysis [Zhang et al., 2010]: 13.8% explicitly temporal
Time for search engines

temporal information needs are frequent
query log analysis [Zhang et al., 2010]: 13.8% explicitly temporal

example information need: topic=“Olympics” time=“[1965,1974]”
Time for search engines

temporal information needs are frequent
query log analysis [Zhang et al., 2010]: 13.8% explicitly temporal

document time constraints are relevant

example information need: topic="Olympics" time="[1965,1974]"
web search with time constraints is difficult
Time for search engines

temporal information needs are frequent
query log analysis [Zhang et al., 2010]: 13.8% explicitly temporal

example information need: topic="Olympics" time="[1965,1974]"

web search with time constraints is difficult

temporal expressions considered as standard words
- 1965 and 1974 make documents relevant
- 1970 will not contribute to relevance
- ten years later [1970] not at all
Event-centric search [ICTIR’16]

idea
- events important in many texts
- events as \( \langle \text{time, place, persons} \rangle \)
Event-centric search [ICTIR’16]

idea
- events important in many texts
- events as \(\langle\text{time, place, persons}\rangle\)

example search query: *Max Planck Institute for Informatics*

<table>
<thead>
<tr>
<th>standard</th>
</tr>
</thead>
<tbody>
<tr>
<td>ranked list of documents</td>
</tr>
</tbody>
</table>

1. doc-1
2. doc-5
3. doc-8
Event-centric search [ICTIR’16]

idea

- events important in many texts
- events as \( \langle \text{time, place, persons} \rangle \)

example search query: *Max Planck Institute for Informatics*

standard

- ranked list of documents

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1.</td>
<td>doc-1</td>
</tr>
<tr>
<td>2.</td>
<td>doc-5</td>
</tr>
<tr>
<td>3.</td>
<td>doc-8</td>
</tr>
</tbody>
</table>

our approach

- documents clustered along important events

<p>| | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1990 (foundation):</td>
<td>doc-1, doc-5</td>
</tr>
<tr>
<td>2000 (10th anniv.):</td>
<td>doc-2, doc-1</td>
</tr>
<tr>
<td>2015 (25th anniv.):</td>
<td>doc-8, doc-5</td>
</tr>
</tbody>
</table>
Time for summarization

- relations between temporal expressions are ignored
Time for summarization

- relations between temporal expressions are ignored

document

- In 2015, something unimportant happened.
- One year later, something important happened.
Time for summarization

- relations between temporal expressions are ignored

   document

- In 2015, something unimportant happened.
- One year later, something important happened.

   useful summaries

- no underspecified/relative expressions without reference time
Time for summarization

- relations between temporal expressions are ignored

document
- In **2015**, something unimportant happened.
- **One year later**, something important happened.

useful summaries
- no underspecified/relative expressions without reference time
- add normalized values (e.g., *One year later [2016]*)
Time-centric corpus analysis [DHd’14, DH’15]

world literature

- Gutenberg / Gutenberg.de corpora
- about 550 authors, 2735 works (1510 – 1950)
Time-centric corpus analysis [DHd’14, DH’15]

world literature
- Gutenberg / Gutenberg.de corpora
- about 550 authors, 2735 works (1510 – 1950)

When does (the German) literature take place?
- analysis of explicit month vs. day-month mentions
Time-centric corpus analysis [DHd’14, DH’15]

world literature
- Gutenberg / Gutenberg.de corpora
- about 550 authors, 2735 works (1510 – 1950)

When does (the German) literature take place?
- analysis of explicit month vs. day-month mentions

quiz:
which month occurs most frequently?
When does (the German) literature take place?

![Graph showing the number of explicit dates by month and day references in the complete corpus.]
Sub-intervals

Authors
The “Calendar boy” of world literature

Jules Verne

month references  
day references

number of explicit dates

JAN  FEB  MAR  APR  MAY  JUN  JUL  AUG  SEP  OCT  NOV  DEC
tiwoli – Today in World Literature

select a day  e.g., today

English quotes

January 11th

As I did not come, Muoth again took the initiative. I received a note from him written in large bold characters, which read:

"Dear Sir,
I usually celebrate my birthday on the 11th January with a few friends. Would you like to come along? It would give us pleasure if we could hear your new sonata on this occasion. What do you think? Have you a colleague with whom you could play it, or shall I send someone to you? Stefan Kranzl would be agreeable. It would please me very much.

HEINRICH MUOTH"

Hermann Hesse
(Wikipedia)

Gertrud
(Wikipedia)
tiwoli – Today in World Literature

select a day

e.g., today

As I did not come, Muoth again took the initiative. I received a note from him written in large bold characters, which read:

"Dear Sir,

I usually celebrate my birthday on the 11th January with a few friends. Would you like to come along? It would give us pleasure if we could hear your new sonata on this occasion. What do you think? Have you a colleague with whom you could play it, or shall I send someone to you? Stefan Kranzl would be agreeable. It would please me very much.

HEINRICH MUOTH

I had not expected that--

Hermann Hesse

(Wikipedia)

Gertrud

(Wikipedia)
What about latent temporal information in texts?
Temponyms [WWW’16]

not only “obvious” temporal expressions as defined in TimeML

Erdal Kuzey

Vinay Setty

Gerhard Weikum
Temponyms [WWW’16]

idea

- standard text phrases may be associated with temporal scopes
- temporal scopes can be found in KBs (or Wikipedia)
Temponyms [WWW’16]

idea
- standard text phrases may be associated with temporal scopes
- temporal scopes can be found in KBs (or Wikipedia)

example phrases
- the Cuban Revolutionary War
- 2008 Mexico City plane crash
Temponyms [WWW’16]

**idea**
- standard text phrases may be associated with temporal scopes
- temporal scopes can be found in KBs (or Wikipedia)

**temporal tagging results**

- the Cuban Revolutionary War 2008
- 2008 Mexico City plane crash
Temponyms [WWW’16]

idea

- standard text phrases may be associated with temporal scopes
- temporal scopes can be found in KBs (or Wikipedia)

temponym tagging results

- [1953-07-26, 1959-01-01]: the Cuban Revolutionary War
- 2008-11-04: 2008 Mexico City plane crash
Temponyms [WWW’16]

idea

- standard text phrases may be associated with temporal scopes
- temporal scopes can be found in KBs (or Wikipedia)

temponym tagging results

<table>
<thead>
<tr>
<th>1953-07-26, 1959-01-01</th>
<th>2008-11-04</th>
</tr>
</thead>
<tbody>
<tr>
<td>the Cuban Revolutionary War</td>
<td>2008 Mexico City plane crash</td>
</tr>
</tbody>
</table>

temponyms add new or more precise temporal information
Temponyms

approaches

- unambiguous temponyms:
  - HeidelTime extension [TempWeb’16]
- all types of temponyms:
  - ILP-based approach with joint inference [WWW’16]
Temponyms

approaches

- unambiguous temponyms:
  - HeidelTime extension [TempWeb’16]
- all types of temponyms:
  - ILP-based approach with joint inference [WWW’16]

examples

- his presidency
- federal election
- ...

Why Time? Temporal Tagging HeidelTime Applications Summary
Temponyms

approaches

- unambiguous temponyms:
  - HeidelTime extension [TempWeb’16]

- all types of temponyms:
  - ILP-based approach with joint inference [WWW’16]

examples

his presidency

- Clinton’s
- Obama’s
- Bush (jr)’s
- Bush (sen)’s

federal election

- CA 2008
- US 2008
- US 2012
ILP-based approach with joint inference [WWW’16]

**first steps**

- identify temponym candidates
  - his presidency
  - federal election
- find KB candidates
- extract and normalize
  - context entities
  - context temporal expressions
ILP-based approach with joint inference [WWW’16]

**first steps**

- identify temponym candidates
  - his presidency
  - federal election
- find KB candidates
- extract and normalize
  - context entities
  - context temporal expressions

**find KB candidates**

- Clinton’s presidency
- Obama’s presidency
- Bush (jr)’s presidency
- Bush (sen)’s presidency
- CA federal election ’08
- US federal election ’08
- US federal election ’12
ILP-based approach with joint inference [WWW’16]

**first steps**

- identify temponym candidates
  - his presidency
  - federal election
- find KB candidates
- extract and normalize
  - context entities
  - context temporal expressions

**find KB candidates**

- Clinton’s presidency
- Obama’s presidency
- Bush (jr)’s presidency
- Bush (sen)’s presidency
- CA federal election ’08
- US federal election ’08
- US federal election ’12

**context**

- Bush, Washington
- 2009, 2008,
ILP-based approach with joint inference [WWW’16]

**first steps**
- Identify temponym candidates
  - his presidency
  - federal election
- Find KB candidates
- Extract and normalize
  - Context entities
  - Context temporal expressions

**ILPs to find optimal temponyms**
Based on coherence and relatedness measures

**Find KB candidates**
- Clinton’s presidency
- Obama’s presidency
- Bush (jr)’s presidency
- Bush (sen)’s presidency
- CA federal election ’08
- US federal election ’08
- US federal election ’12

**Context**
- Bush, Washington
- 2009, 2008,
Summary

- Why temporal information?
- What’s temporal tagging?
- Why domain-sensitive temporal tagging?
- What applications can exploit temporal information and how?
Summary

- temporal information
  - frequent, important
Summary

- temporal information
  - frequent, important
- temporal tagging
  - extraction and normalization of temporal expressions
- domain-sensitive temporal tagging
  - different domains, different challenges
  - taggers tailored towards one domain, quality drop on others
Summary

- temporal information
  - frequent, important
- temporal tagging
  - extraction and normalization of temporal expressions
- domain-sensitive temporal tagging
  - different domains, different challenges
  - taggers tailored towards one domain, quality drop on others
- many applications can benefit
  - in multiple ways
- latent temporal information in texts
  - challenging, but useful to further enrich documents
Time for question answering

- When was Bill Clinton born?
- Who won last year’s Superbowl?
- What money did they use in Spain before 2002?
Time for question answering

Various types of temporal questions

- **When** was Bill Clinton born?
- Who won last year’s Superbowl?
- What money did they use in Spain before 2002?

This is ongoing work...
Time for further information
Why Time? Temporal Tagging

HeidelTime

Applications

Summary

Time for further information

github

iOS & Android app

CS library

Thank you! – Time for your questions...

Joint Lecture Series – January 11, 2017

© Jannik Strötgen