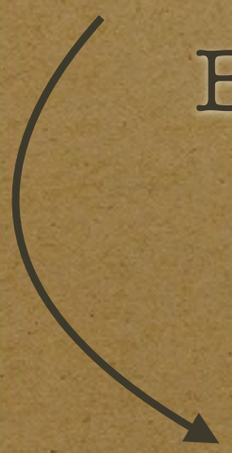
SCULPT
A Schema Language for Tabular Data on the Web

Wim Martens
Bayreuth

Frank Neven
Hasselt

Stijn Vansummeren
Brussels



this one is me

WWW 2015
Florence

Tabular Data is...

Tabular Data is...

```
,ENTEBBE AIR, FT PORTAL, GONDOKORO, GULU, HOIMA, JINJA, KABALE, MASAKA, MASINDI, MBALE, MBARARA, MOROTO
1905.04, 25.60, 24.17, 34.67,-99.00,-99.00, 29.06,-99.00, 24.50,-99.00,-99.00, 26.50,-99.00,-99.00
1905.13, 27.30, 25.61, 36.50,-99.00,-99.00, 31.44,-99.00, 26.67,-99.00,-99.00, 27.00,-99.00,-99.00
1905.21, 24.90, 25.44, 37.39,-99.00,-99.00, 28.78,-99.00, 25.06,-99.00,-99.00, 27.17,-99.00,-99.00
1905.29, 25.10, 25.56, 35.28,-99.00,-99.00, 28.72,-99.00, 24.33,-99.00,-99.00, 27.67,-99.00,-99.00
1905.38, 24.30,-99.00, 33.06,-99.00,-99.00, 28.78,-99.00, 25.08,-99.00,-99.00, 27.54,-99.00,-99.00
```

Temperature readings from weather stations in Africa

Tabular Data is...

```
,ENTEBBE AIR, FT PORTAL, GONDOKORO, GULU, HOIMA, JINJA, KABALE, MASAKA, MASINDI, MBALE, MBARARA, MOROTO
1905.04, 25.60, 24.17, 34.67,-99.00,-99.00, 29.06,-99.00, 24.50,-99.00,-99.00, 26.50,-99.00,-99.00
1905.13, 27.30, 25.61, 36.50,-99.00,-99.00, 31.44,-99.00, 26.67,-99.00,-99.00, 27.00,-99.00,-99.00
1905.21, 24.90, 25.44, 37.39,-99.00,-99.00, 28.78,-99.00, 25.06,-99.00,-99.00, 27.17,-99.00,-99.00
1905.29, 25.10, 25.56, 35.28,-99.00,-99.00, 28.72,-99.00, 24.33,-99.00,-99.00, 27.67,-99.00,-99.00
1905.38, 24.30,-99.00, 33.06,-99.00,-99.00, 28.78,-99.00, 25.08,-99.00,-99.00, 27.54,-99.00,-99.00
```

Temperature readings from weather stations in Africa

```
subject predicate     object     provenance
:e4     type          PER
:e4     mention       "Bart"     D00124  283-286
:e4     mention       "Jojo"     D00124  145-149  0.9
:e4     per:siblings  :e7        D00124  283-286  173-179  274-281
:e4     per:age       "10"       D00124  180-181  173-179  182-191  0.9
:e4     per:parent    :e9        D00124  180-181  381-380  399-406  D00101  220-225  230-233  201-210
```

US National Institute of Standards and Technology (NIST),
Cold Start Knowledge Base Population Task

Examples taken from the W3C CSV on the Web WG use cases

Tabular Data is...

... text data that is structured in rows and columns

```
,ENTEBBE AIR, FT PORTAL, GONDOKORO, GULU, HOIMA, JINJA, KABALE, MASAKA, MASINDI, MBALE, MBARARA, MOROTO
1905.04, 25.60, 24.17, 34.67,-99.00,-99.00, 29.06,-99.00, 24.50,-99.00,-99.00, 26.50,-99.00,-99.00
1905.13, 27.30, 25.61, 36.50,-99.00,-99.00, 31.44,-99.00, 26.67,-99.00,-99.00, 27.00,-99.00,-99.00
1905.21, 24.90, 25.44, 37.39,-99.00,-99.00, 28.78,-99.00, 25.06,-99.00,-99.00, 27.17,-99.00,-99.00
1905.29, 25.10, 25.56, 35.28,-99.00,-99.00, 28.72,-99.00, 24.33,-99.00,-99.00, 27.67,-99.00,-99.00
1905.38, 24.30,-99.00, 33.06,-99.00,-99.00, 28.78,-99.00, 25.08,-99.00,-99.00, 27.54,-99.00,-99.00
```

Temperature readings from weather stations in Africa

```
subject predicate     object     provenance
:e4     type          PER
:e4     mention       "Bart"     D00124  283-286
:e4     mention       "Jojo"     D00124  145-149  0.9
:e4     per:siblings  :e7        D00124  283-286  173-179  274-281
:e4     per:age       "10"       D00124  180-181  173-179  182-191  0.9
:e4     per:parent    :e9        D00124  180-181  381-380  399-406  D00101  220-225  230-233  201-210
```

US National Institute of Standards and Technology (NIST),
Cold Start Knowledge Base Population Task

Examples taken from the W3C CSV on the Web WG use cases

Tabular Data

A lot of data on the Web is **tabular**

Tabular Data

A lot of data on the Web is **tabular**

spreadsheets

Tabular Data

A lot of data on the Web is **tabular**

spreadsheets

comma-separated-value files (CSV)

Tabular Data

A lot of data on the Web is **tabular**

spreadsheets

comma-separated-value files (CSV)

HTML tables

Tabular Data

A lot of data on the Web is **tabular**

spreadsheets

comma-separated-value files (CSV)

HTML tables

...

Tabular Data

A lot of data on the Web is **tabular**

spreadsheets

comma-separated-value files (CSV)

HTML tables

...

"Over 90% of open data is tabular"

-Jeni Tennison

(Open Data Institute and W3C CSV on the Web WG)

But...

But...

...tabular data / CSV has many irregularities

But...

...tabular data / CSV has many irregularities
because there is **no standard**

But...

...tabular data / CSV has many irregularities
because there is **no standard**

"2/3 of 'CSV' files on data.gov.uk are
not machine-readable
[in an elegant way]"

-Jeni Tennison

(Open Data Institute and W3C CSV on the Web WG)

But...

...tabular data / CSV has many irregularities
because there is **no standard**

"2/3 of 'CSV' files on data.gov.uk are
not machine-readable
[in an elegant way]"

-Jeni Tennison
(Open Data Institute and W3C CSV on the Web WG)

This is why the W3C is working on a standard for CSV

Standardizing CSV?

In the end, you'd like to have a simple way to

describe

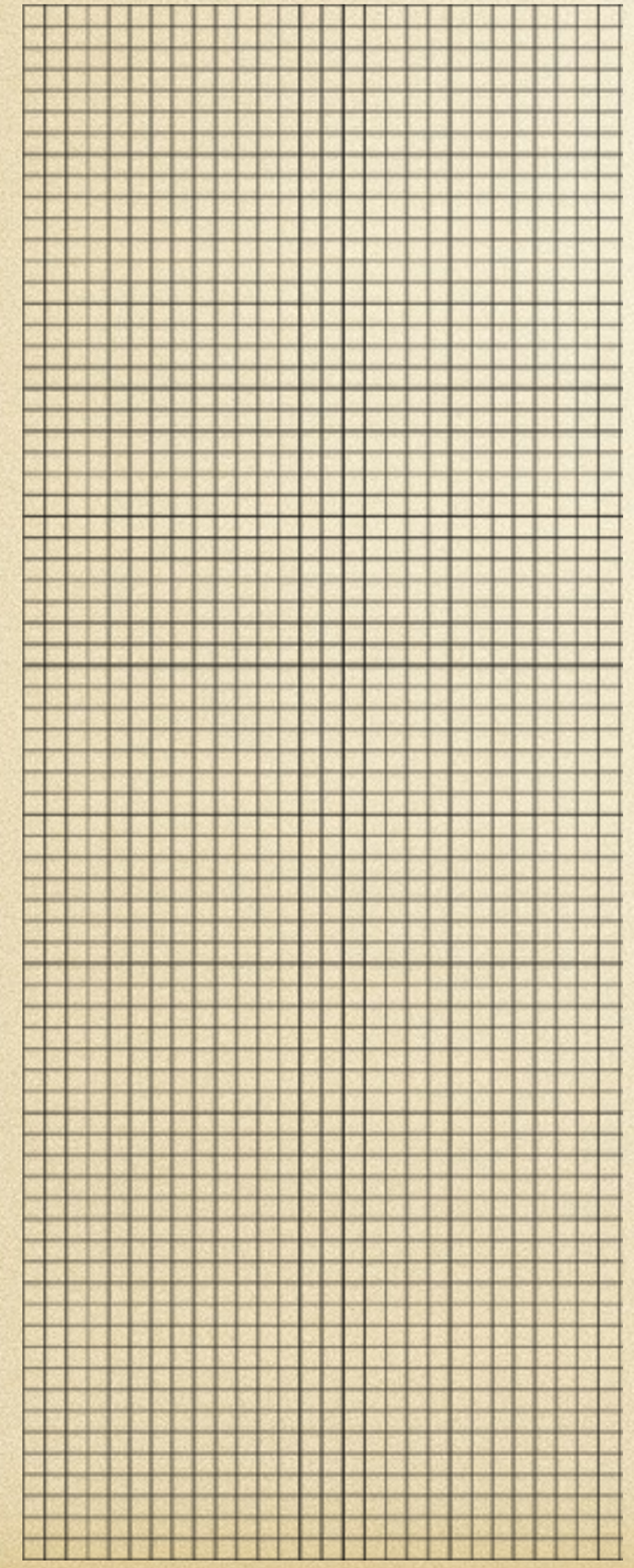
and

manipulate

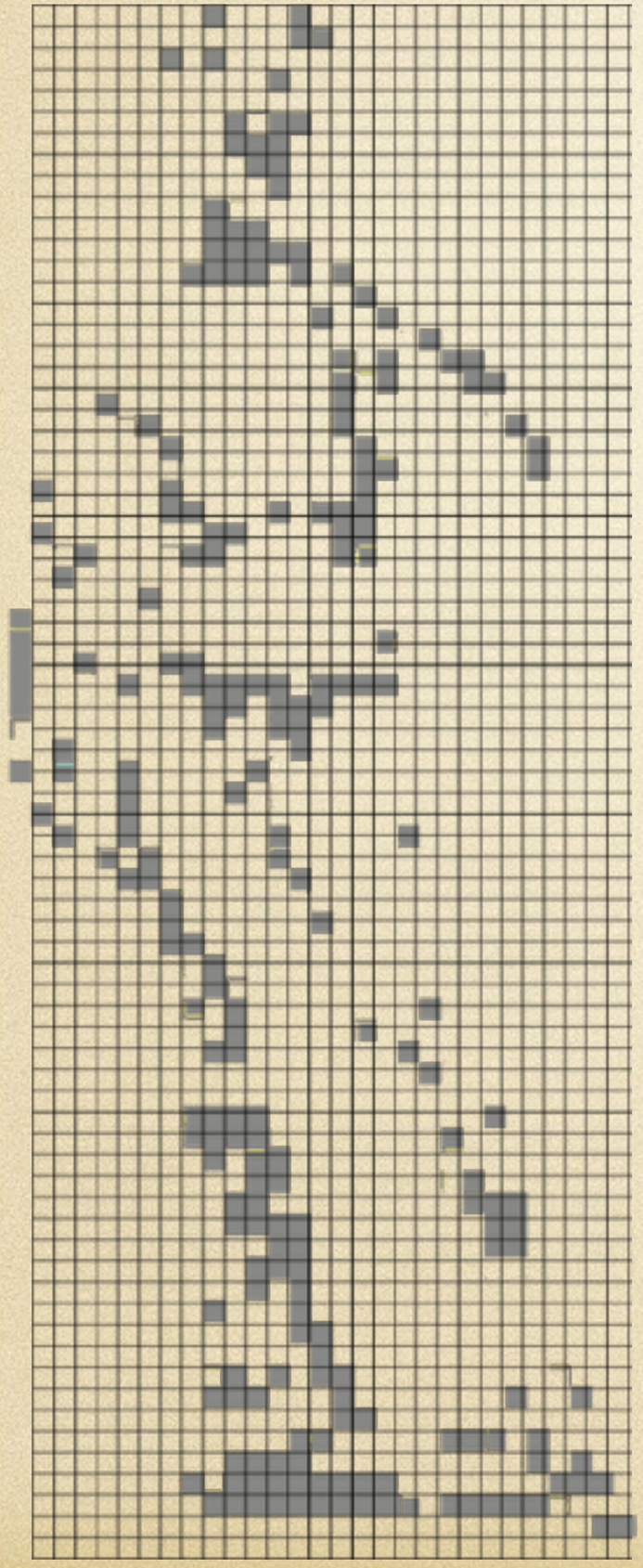
tabular data

What do I mean by that?

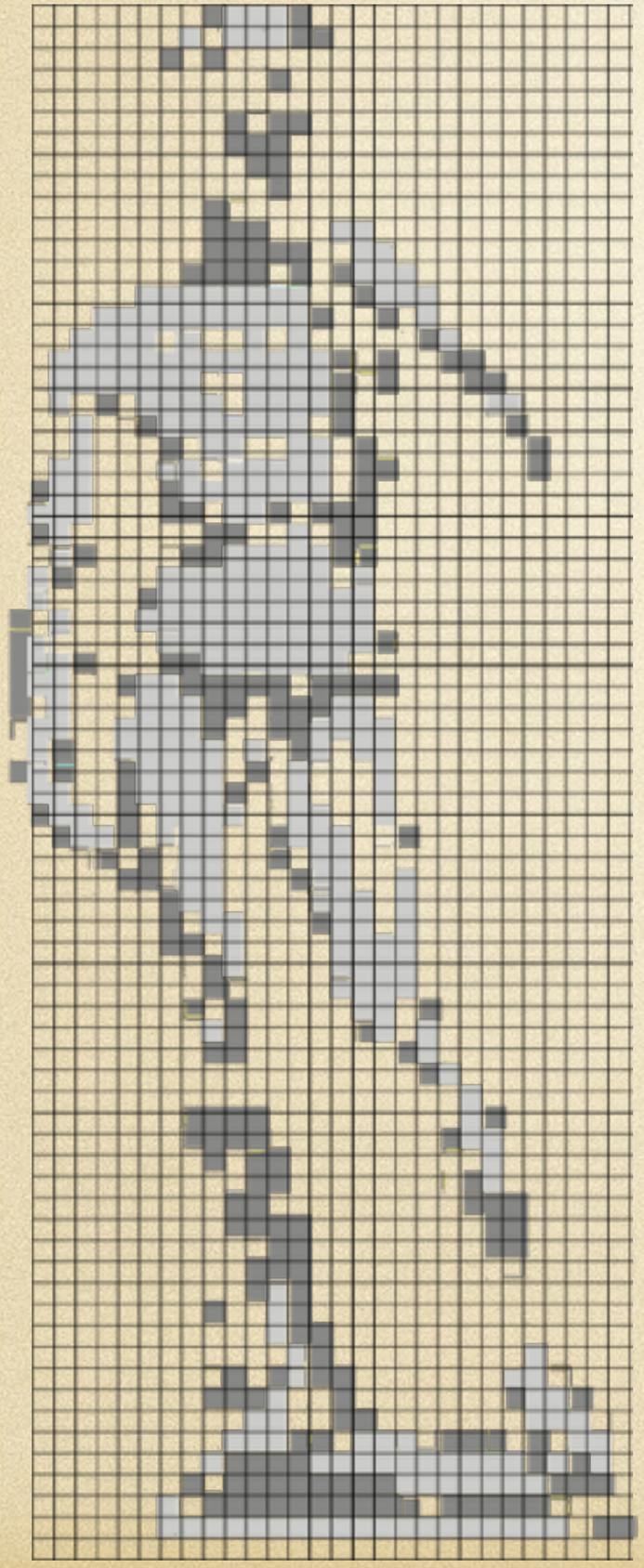
What do I mean by that?



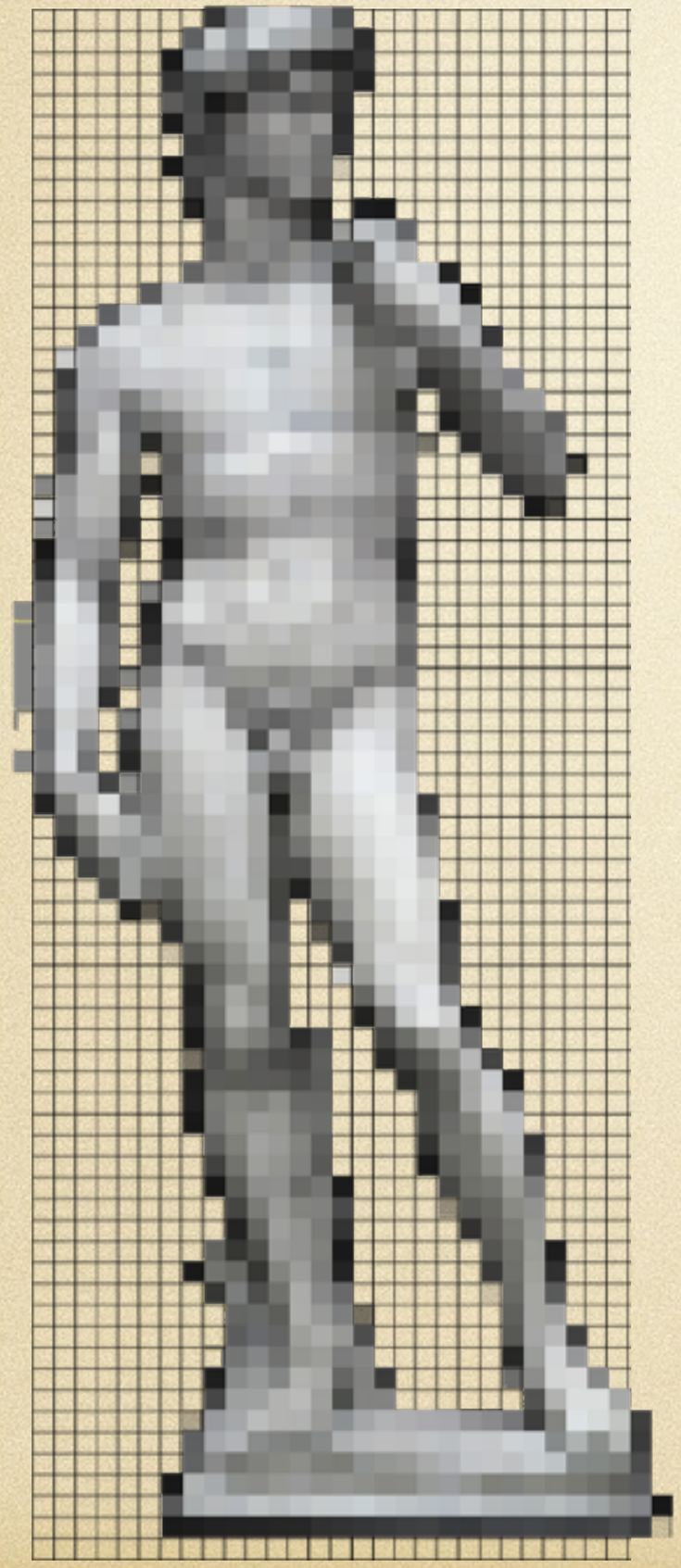
What do I mean by that?



What do I mean by that?



What do I mean by that?



You want a tool to describe
the logical structure
of the cells

So that you can

- define a schema
- select, transform, export cell values

You need a **schema language**,
a.k.a. **meta data format**

W3C Meta Data, current state

The W3C is currently working on
a metadata format for tabular data

W3C Meta Data, current state

The W3C is currently working on
a metadata format for tabular data

It allows to specify the format of cells,
but its capabilities are limited

W3C Meta Data, current state

The W3C is currently working on
a metadata format for tabular data

It allows to specify the format of cells,
but its capabilities are limited

On the structural level, it can basically say:

- cell x contains the XSD data type [...]
- the column of cell x contains the XSD data type [...]

W3C Meta Data, current state

The W3C is currently working on
a metadata format for tabular data

It allows to specify the format of cells,
but its capabilities are limited

On the structural level, it can basically say:

- cell x contains the XSD data type [...]
- the column of cell x contains the XSD data type [...]

```
        , ENTEBBE AIR, FT PORTAL, GONDOKORO,   GULU, [...]
1905.04,       25.60,     24.17,     34.67, -99.00, [...]
1905.13,       27.30,     25.61,     36.50, -99.00, [...]
1905.21,       24.90,     25.44,     37.39, -99.00, [...]
1905.29,       25.10,     25.56,     35.28, -99.00, [...]
1905.38,       24.30,    -99.00,     33.06, -99.00, [...]
1905.46,       25.30,    -99.00,     32.44, -99.00, [...]
[...]
```

(W3C Use Cases and Requirements, Use Case 3)

One Data Type Per Column?

(W3C Use Cases and Requirements, Use Case 13)

subject	predicate	object	provenance							
:e4	type	PER								
:e4	mention	"Bart"	D00124	283-286						
:e4	mention	"Jojo"	D00124	145-149	0.9					
:e4	per:siblings	:e7	D00124	283-286	173-179	274-281				
:e4	per:age	"10"	D00124	180-181	173-179	182-191	0.9			
:e4	per:parent	:e9	D00124	180-181	381-380	399-406	D00101	220-225	230-233	201-210

One Data Type Per Column?

(W3C Use Cases and Requirements, Use Case 13)

subject	predicate	object	provenance							
:e4	type	PER								
:e4	mention	"Bart"	D00124	283-286						
:e4	mention	"Jojo"	D00124	145-149	0.9					
:e4	per:siblings	:e7	D00124	283-286	173-179	274-281				
:e4	per:age	"10"	D00124	180-181	173-179	182-191	0.9			
:e4	per:parent	:e9	D00124	180-181	381-380	399-406	D00101	220-225	230-233	201-210

Here, we see different data types per column:

document IDs

positions in a document

certainty values

One Data Type Per Column?

(W3C Use Cases and Requirements, Use Case 13)

subject	predicate	object	provenance							
:e4	type	PER								
:e4	mention	"Bart"	D00124	283-286						
:e4	mention	"Jojo"	D00124	145-149	0.9					
:e4	per:siblings	:e7	D00124	283-286	173-179	274-281				
:e4	per:age	"10"	D00124	180-181	173-179	182-191	0.9			
:e4	per:parent	:e9	D00124	180-181	381-380	399-406	D00101	220-225	230-233	201-210

:e4	per:age	"10"	D00124	180-181	0.9
:e4	per:age	"10"	D00124	173-179	0.9
:e4	per:age	"10"	D00124	182-191	0.9
:e4	per:parent	:e9	D00124	180-181	
:e4	per:parent	:e9	D00124	381-380	
:e4	per:parent	:e9	D00124	399-406	
:e4	per:parent	:e9	D00101	220-225	
:e4	per:parent	:e9	D00101	230-233	
:e4	per:parent	:e9	D00101	201-210	

You want to reason about these different types in a column

What can research do to help?

SCULPT

SChema for **U**n-**L**ocking and **P**rocessing **T**abular data

"Every block of stone has a statue inside it and it is the task of the sculptor to discover it"

-Michelangelo

SCULPT is about describing the statue

(Image: Caricato da Sailko, public domain, wikipedia)

SCULPT

SChema for **U**n-**L**ocking and **P**rocessing **T**abular data

"Every block of data has structure inside it and it is the task of the schema-designer to describe it"

-Michelangelo

(what he probably meant)

The schema-designer is the Michelangelo of the data

SCULPT is about describing the statue

(Image: Caricato da Sailko, public domain, wikipedia)

SCULPT

A simple language

Serves as a schema language
for tabular data

Serves as a basis
for node selection,
for a transformation language

Built on solid foundations

Hopefully, serves as a
source of inspiration

SCULPT, general principle

Describe the structure of tabular data in three stages:

1. It describes what the cells are → (trivial)

2. It describes the content of **single cells** → (easy)

3. It describes the **relationship between cells** → (main machinery)

SCULPT, general principle

Describe the structure of tabular data in three stages:

1. It describes what the cells are

by specifying row / column delimiter

2. It describes the content of **single cells**

each cell's content is matched against a regex,
which we'll interpret as a "data type"

(Alternatively, one could also use
XML Schema single types)

SCULPT, general principle

Describe the structure of tabular data in three stages:

After the 2nd stage, the each cell of the table has a **set of datatypes**

```
          , ENTEBBE AIR, FT PORTAL, GONDOKORO,   GULU, [...]
1905.04,        25.60,     24.17,     34.67, -99.00, [...]
1905.13,        27.30,     25.61,     36.50, -99.00, [...]
1905.21,        24.90,     25.44,     37.39, -99.00, [...]
1905.29,        25.10,     25.56,     35.28, -99.00, [...]
1905.38,        24.30,    -99.00,     33.06, -99.00, [...]
[...]
```

```
          ,  ENTEBBE AIR,  FT PORTAL,   GONDOKORO,   GULU, [...]
Timestamp,  Temperature, Temperature, Temperature,  Dummy, [...]
Timestamp,  Temperature, Temperature, Temperature,  Dummy, [...]
Timestamp,  Temperature, Temperature, Temperature,  Dummy, [...]
Timestamp,  Temperature, Temperature, Temperature,  Dummy, [...]
Timestamp,  Temperature,       Dummy, Temperature,  Dummy, [...]
```

SCULPT, general principle

We describe the structure of tabular data in three stages:

3. It describes the **relationship between cells**

This is the **core of SCULPT**

```
          ,  ENTEBBE AIR,  FT PORTAL,   GONDOKORO,   GULU, [...]
Timestamp,  Temperature,Temperature,Temperature,  Dummy, [...]
Timestamp,  Temperature,Temperature,Temperature,  Dummy, [...]
Timestamp,  Temperature,Temperature,Temperature,  Dummy, [...]
Timestamp,  Temperature,Temperature,Temperature,  Dummy, [...]
Timestamp,  Temperature,      Dummy,Temperature,  Dummy, [...]
```

SCULPT, general principle

We describe the structure of tabular data in three stages:

3. It describes the **relationship between cells**

This is the **core of SCULPT**

```
          ,  ENTEBBE AIR,  FT PORTAL,   GONDOKORO,   GULU, [...]
Timestamp,  Temperature,Temperature,Temperature,  Dummy, [...]
Timestamp,  Temperature,Temperature,Temperature,  Dummy, [...]
Timestamp,  Temperature,Temperature,Temperature,  Dummy, [...]
Timestamp,  Temperature,Temperature,Temperature,  Dummy, [...]
Timestamp,  Temperature,      Dummy,Temperature,  Dummy, [...]
```

row(1) -> Empty, ENTEBBE AIR, FT PORTAL, GONDOKORO, GULU

col(ENTEBBE AIR) -> Temperature

col(FT PORTAL) -> Temperature | Dummy

SCULPT, general principle

We describe the structure of tabular data in three stages:

3. It describes the **relationship between cells**

This is the **core of SCULPT**

General idea:
the schema has a set of rules

```
<selection expression>  ->  <content expression>
```

selects a **region**
(set of cells)
in the table

describes how the
region should look like

SCULPT, general principle

We describe the structure of tabular data in three stages:

3. It describes the **relationship between cells**

This is the **core of SCULPT**

General idea:
the schema has a set of rules

```
<selection expression>  ->  <content expression>
```

selects a **region**
(set of cells)
in the table

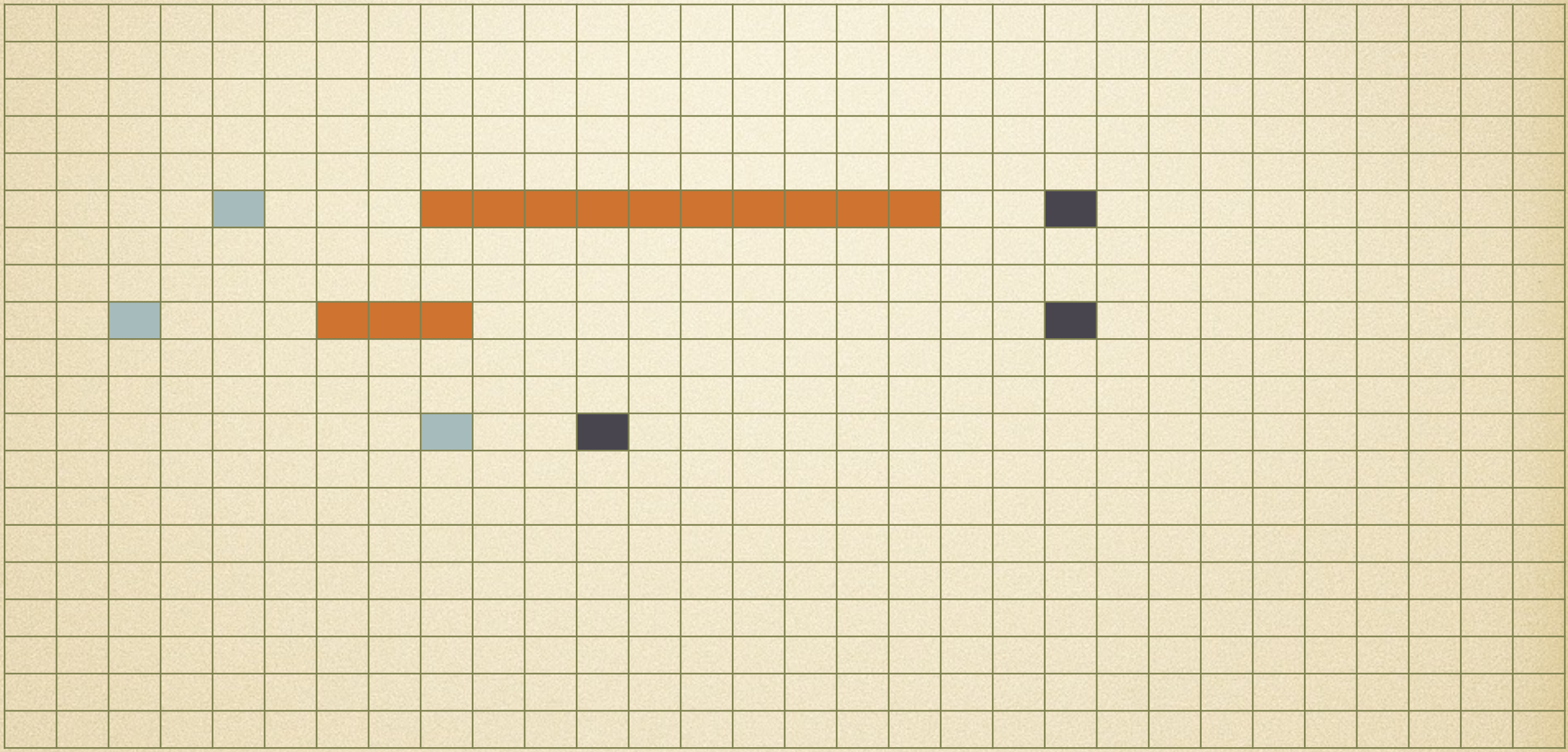
describes how the
region should look like

If the data satisfies these rules, it is valid / well-formed

Token Structure (1/3)

<selection expression> -> <content expression>

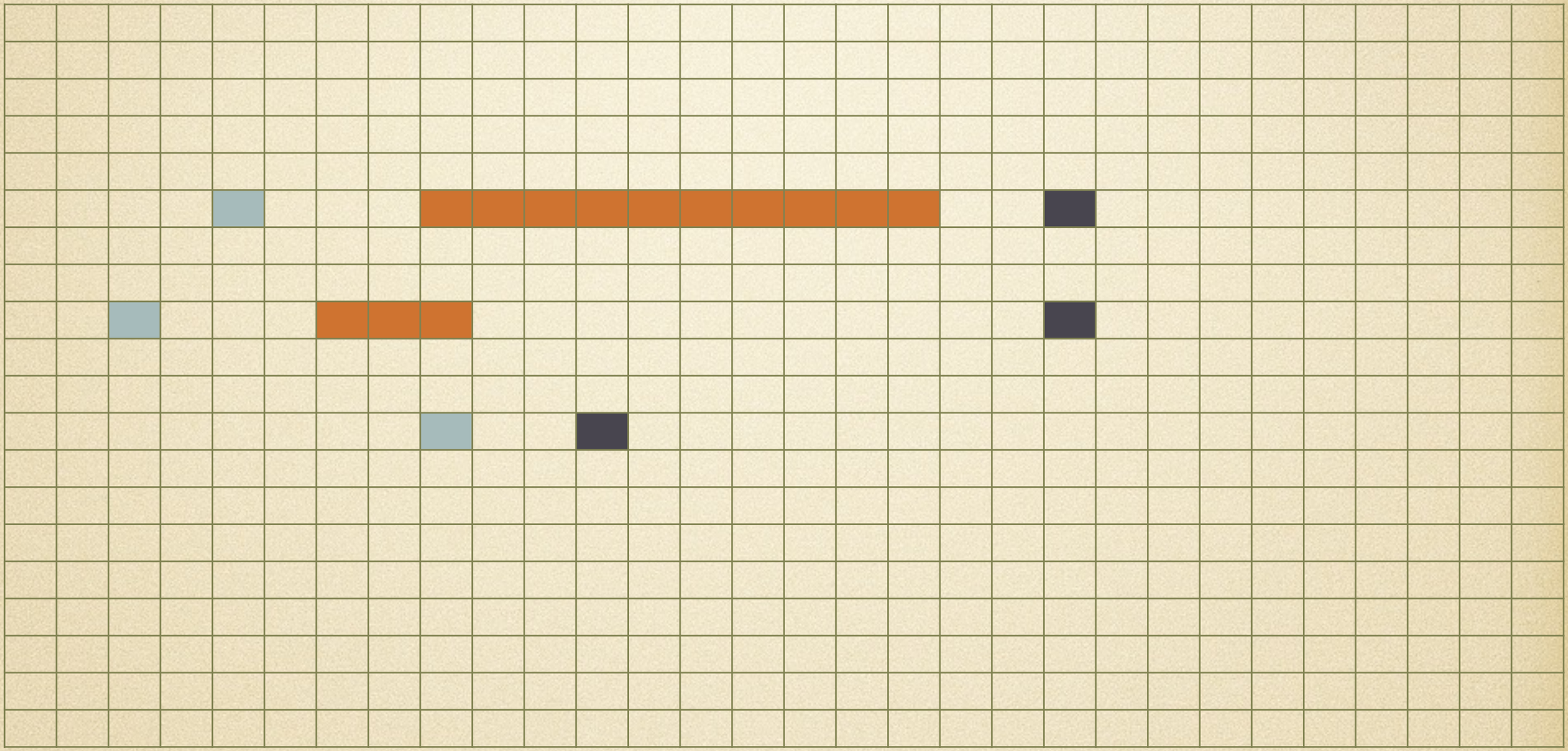
Token Structure (2/3)



<selection expression> -> <content expression>

region is matched
row by row

Token Structure (3/3)



<selection expression> => <content expression>

entire region
is matched

(, * ,)*

SCULPT by Example

Data:

```
subject  predicate     object  provenance
:e4      type          PER
:e4      mention       "Bart"  D00124  283-286
:e4      mention       "Jojo"  D00124  145-149  0.9
:e4      per:siblings  :e7     D00124  283-286  173-179  274-281
:e4      per:age       "10"    D00124  180-181  173-179  182-191  0.9
:e4      per:parent    :e9     D00124  180-181  381-380  399-406  D00101  220-225  230-233  201-210
```

Schema:

```
% Simple datatypes
rdf-uri      rdf-lit
doc-ID       position       certainty
word         entity-type

% Rules
row(1) -> subject, predicate, object, provenance
col(subject)   -> rdf-uri
col(predicate) -> word | rdf-uri
col(object)    -> rdf-lit | rdf-uri | entity-type

down+(right*(provenance))  ->  (doc-ID, position*, certainty?)*
```

How are Rules Defined?

In the rules

```
<selection expression>  ->  <content expression>
<selection expression>  =>  <content expression>
```

the selection expression is based on core **XPath**
(it selects nodes)

XPath is powerful, expressive,
and has linear time evaluation

How are Rules Defined?

In the rules

```
<selection expression>  ->  <content expression>

<selection expression>  =>  <content expression>
```

the selection expression is based on core **XPath**
(it selects nodes)

the content expression is just
a **regular expression using datatypes**

XPath is powerful, expressive,
and has linear time evaluation

SCULPT is Simple, Powerful, and Efficient

Theorem:
Given a tabular document **D** and a Sculpt schema **S**, we can test in linear-time* if **D** satisfies **S**

*combined complexity

SCULPT is Simple, Powerful, and Efficient

Theorem:
Given a tabular document **D** and a Sculpt schema **S**, we can test in linear-time* if **D** satisfies **S**

*combined complexity

Theorem:
Streaming validation works too

(precise statement can be found in the paper)

SCULPT is Simple, Powerful, and Efficient and is a basis for a transformation language

```
subject  predicate     object  provenance
:e4      type          PER
:e4      mention       "Bart"  D00124  283-286
:e4      mention       "Jojo"  D00124  145-149  0.9
:e4      per:siblings  :e7     D00124  283-286  173-179  274-281
:e4      per:age       "10"    D00124  180-181  173-179  182-191  0.9
:e4      per:parent    :e9     D00124  180-181  381-380  399-406  D00101  220-225  230-233  201-210
```

If you can identify and select regions,
transforming them becomes easy

SCULPT is Simple, Powerful, and Efficient and is a basis for a transformation language

```
subject  predicate     object  provenance
:e4      type          PER
:e4      mention       "Bart"  D00124  283-286
:e4      mention       "Jojo"  D00124  145-149  0.9
:e4      per:siblings  :e7     D00124  283-286  173-179  274-281
:e4      per:age       "10"    D00124  180-181  173-179  182-191  0.9
:e4      per:parent    :e9     D00124  180-181  381-380  399-406  D00101  220-225  230-233  201-210
```

If you can identify and select regions, transforming them becomes easy

```
        , ENTEBBE AIR, FT PORTAL, GONDOKORO,   GULU, [...]
1905.04,       25.60,     24.17,     34.67, -99.00, [...]
1905.13,       27.30,     25.61,     36.50, -99.00, [...]
1905.21,       24.90,     25.44,     37.39, -99.00, [...]
1905.29,       25.10,     25.56,     35.28, -99.00, [...]
1905.38,       24.30,    -99.00,     33.06, -99.00, [...]
[...]
```

```
SITE[down*::Temperature]
```

```
SITE = [A-Z]*
```

SCULPT is Simple, Powerful, and Efficient
and is a basis for a transformation language

This is **not** about

SCULPT is Simple, Powerful, and Efficient
and is a basis for a transformation language

This is **not** about

a bunch of crazy researchers

SCULPT is Simple, Powerful, and Efficient
and is a basis for a transformation language

This is **not** about

a bunch of crazy researchers

trying to get some weird feature in some standard

SCULPT is Simple, Powerful, and Efficient
and is a basis for a transformation language

This is **not** about

a bunch of crazy researchers

trying to get some weird feature in some standard

Actually,

SCULPT is Simple, Powerful, and Efficient
and is a basis for a transformation language

This is **not** about

a bunch of crazy researchers

trying to get some weird feature in some standard

Actually,

we're seeing a challenge in the language

SCULPT is Simple, Powerful, and Efficient
and is a basis for a transformation language

This is **not** about

a bunch of crazy researchers

trying to get some weird feature in some standard

Actually,

we're seeing a challenge in the language

and we're seeing how it can be addressed

SCULPT is Simple, Powerful, and Efficient
and is a basis for a transformation language

We hope that the W3C is listening

and can take some inspiration from us

SCULPT is Simple, Powerful, and Efficient
and is a basis for a transformation language

We hope that the W3C is listening

and can take some inspiration from us

to make their meta-data format

SCULPT is Simple, Powerful, and Efficient
and is a basis for a transformation language

We hope that the W3C is listening

and can take some inspiration from us

to make their meta-data format

more expressive,

SCULPT is Simple, Powerful, and Efficient
and is a basis for a transformation language

We hope that the W3C is listening

and can take some inspiration from us

to make their meta-data format

more expressive,

better capable of dealing with their use cases,

SCULPT is Simple, Powerful, and Efficient
and is a basis for a transformation language

We hope that the W3C is listening

and can take some inspiration from us

to make their meta-data format

more expressive,

better capable of dealing with their use cases,

without a cost in complexity

SCULPT is Simple, Powerful, and Efficient
and is a basis for a transformation language

We hope that the W3C is listening

and can take some inspiration from us

to make their meta-data format

more expressive,

better capable of dealing with their use cases,

without a cost in complexity

Thank you!

Backup

SCULPT by Example

Data:

```
subject  predicate     object  provenance
:e4      type          PER
:e4      mention       "Bart"  D00124  283-286
:e4      mention       "Jojo"  D00124  145-149  0.9
:e4      per:siblings  :e7     D00124  283-286  173-179  274-281
:e4      per:age       "10"    D00124  180-181  173-179  182-191  0.9
:e4      per:parent    :e9     D00124  180-181  381-380  399-406  D00101  220-225  230-233  201-210
```

The complete schema:

```
Col delim: \t
Row delim: \n
```

```
% Tokens / data types
rdf-uri      = [a-zA-Z0-9]*:[a-zA-Z0-9]*
rdf-lit      = \"[a-zA-Z0-9]*\"
doc-ID       = D[0-9]{5}
position     = [0-9]{3}\-[0-9]{3}
certainty    = [0-9]\.[0-9]
word         = [a-z]*
entity-type = PER | ORG | GPE

% Rules
row(1) -> subject, predicate, object, provenance
col(subject)   -> rdf-uri
col(predicate) -> word | rdf-uri
col(object)    -> rdf-lit | rdf-uri | entity-type
down+(right*(provenance))
               -> (doc-ID, position*, certainty?)*
```