# Semantic Search for Quantity Expressions

Tom Wiesing

Supervisor: Michael Kohlhase
Co-supervisor: Tobias Preusser

May 20, 2015
110392 Guided Research Applied and Computational Mathematics & Thesis

# Overview

# Overview

- Motivation: Problem and State Of The Art

# Overview

- Motivation: Problem and State Of The Art
- Our Approach: Structure Of The Search Engine

# Overview

- Motivation: Problem and State Of The Art
- Our Approach: Structure Of The Search Engine
  - The Unit System

# Overview

- Motivation: Problem and State Of The Art
- Our Approach: Structure Of The Search Engine
  - The Unit System
  - The Search Algorithm

# Overview

- Motivation: Problem and State Of The Art
- Our Approach: Structure Of The Search Engine
  - The Unit System
  - The Search Algorithm
- Conclusion: The Implementation

# Overview

- Motivation: Problem and State Of The Art
- Our Approach: Structure Of The Search Engine
  - The Unit System
  - The Search Algorithm
- Conclusion: The Implementation
- Time for Questions

# Motivation (1)

- We use units every day

# Motivation (1)

- We use units every day
- We encounter them everywhere:

# Motivation (1)

- We use units every day
- We encounter them everywhere:
  - When driving, there are speed limits, for example: 

$\frac{\text{km}}{\text{h}}$

# Motivation (1)

- We use units every day
- We encounter them everywhere:
  - When driving, there are speed limits, for example: 

$\frac{\text{km}}{\text{h}}$
  - When baking, it often says in recepies something like: “add 3 tea spoons of sugar”

# Motivation (1)

- We use units every day
- We encounter them everywhere:
  - When driving, there are speed limits, for example: 

$\frac{\text{km}}{\text{h}}$
  - When baking, it often says in recepies something like: "add 3 tea spoons of sugar"
  - When shopping for shoes there are different sizes

# Motivation (1)

- We use units every day
- We encounter them everywhere:
  - When driving, there are speed limits, for example: 

$\frac{\text{km}}{\text{h}}$
  - When baking, it often says in recepies something like: "add 3 tea spoons of sugar"
  - When shopping for shoes there are different sizes
- In scientific papers they occur a lot

# Motivation (1)

- We use units every day
- We encounter them everywhere:
  - When driving, there are speed limits, for example: 

$\frac{\text{km}}{\text{h}}$
  - When baking, it often says in recepies something like: "add 3 tea spoons of sugar"
  - When shopping for shoes there are different sizes
- In scientific papers they occur a lot
- everything which somehow models a real system has at least one quantity expression

# Motivation (1)

- We use units every day
- We encounter them everywhere:
  - When driving, there are speed limits, for example: 

$\frac{\text{km}}{\text{h}}$
  - When baking, it often says in recepies something like: "add 3 tea spoons of sugar"
  - When shopping for shoes there are different sizes
- In scientific papers they occur a lot
- everything which somehow models a real system has at least one quantity expression
- everything is quantified

# Motivation (2)

- within one paper, commonly only one type of units is used

# Motivation (2)

- within one paper, commonly only one type of units is used
- In general there are **a lot** of **different** units to describe **the same** quantity

# Motivation (2)

- within one paper, commonly only one type of units is used
- In general there are **a lot** of **different** units to describe **the same** quantity
- Just for lengths:

# Motivation (2)

- within one paper, commonly only one type of units is used
- In general there are **a lot** of **different** units to describe **the same** quantity
- Just for lengths:

# Motivation (2)

- within one paper, commonly only one type of units is used
- In general there are **a lot** of **different** units to describe **the same** quantity
- Just for lengths: *Meter*,

# Motivation (2)

- within one paper, commonly only one type of units is used
- In general there are **a lot** of **different** units to describe **the same** quantity
- Just for lengths: *Meter*, *Inch*,

# Motivation (2)

- within one paper, commonly only one type of units is used
- In general there are **a lot** of **different** units to describe **the same** quantity
- Just for lengths: *Meter*, *Inch*, *Foot*,

# Motivation (2)

- within one paper, commonly only one type of units is used
- In general there are **a lot** of **different** units to describe **the same** quantity
- Just for lengths: *Meter*, *Inch*, *Foot*, *Mile*,

# Motivation (2)

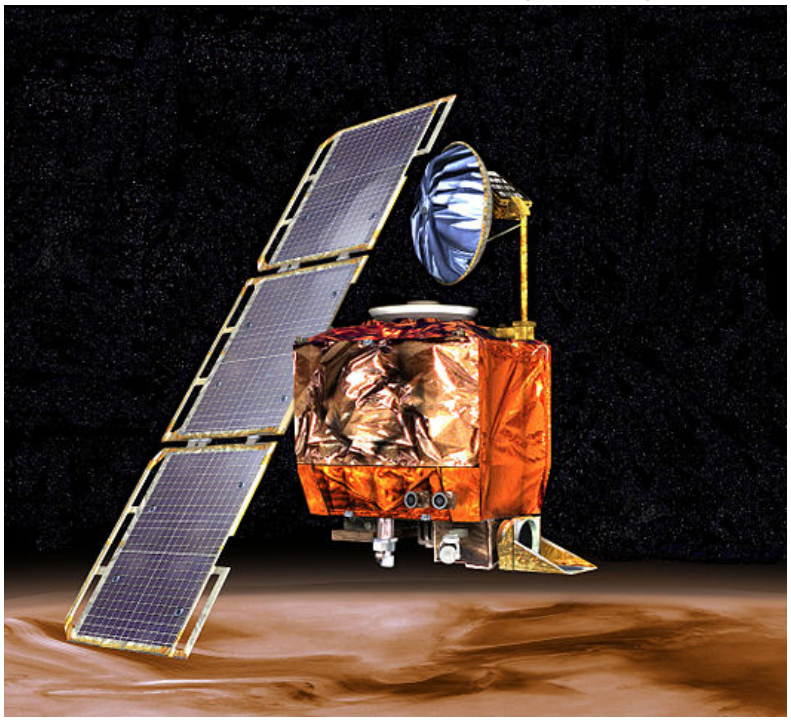
- within one paper, commonly only one type of units is used
- In general there are **a lot** of **different** units to describe **the same** quantity
- Just for lengths: *Meter*, *Inch*, *Foot*, *Mile*, *Nautical Mile*,

# Motivation (2)

- within one paper, commonly only one type of units is used
- In general there are **a lot** of **different** units to describe **the same** quantity
- Just for lengths: *Meter*, *Inch*, *Foot*, *Mile*, *Nautical Mile*, ...
- This can cause problems when not converting properly

# Motivation (2)

- within one paper, commonly only one type of units is used
- In general there are **a lot** of **different** units to describe **the same** quantity
- Just for lengths: *Meter*, *Inch*, *Foot*, *Mile*, *Nautical Mile*, ...
- This can cause problems when not converting properly
  - Mars Climate Orbiter (1999)



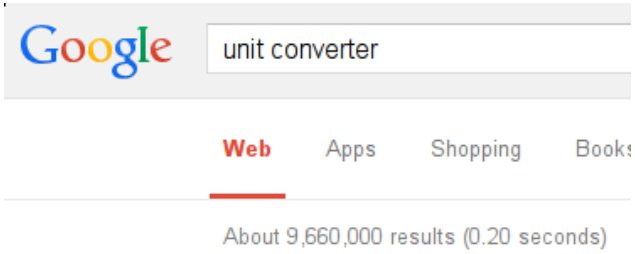
# Motivation (3)

# Motivation (3)

- Most common solution: Unit Converters

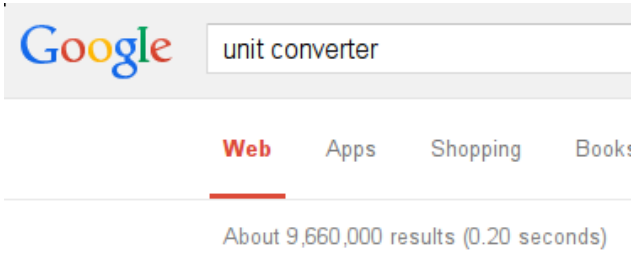
# Motivation (3)

- Most common solution: Unit Converters
  - There are a lot of these

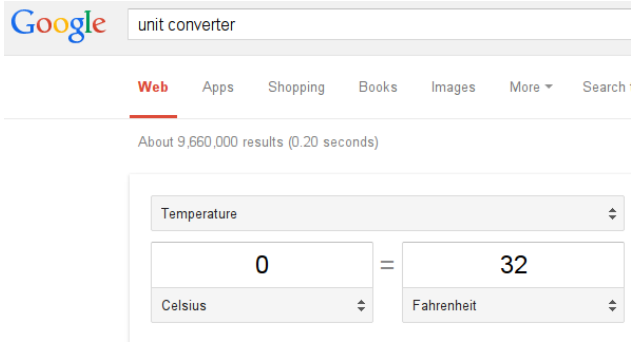


# Motivation (3)

- Most common solution: Unit Converters
  - There are a lot of these




  - Google itself has one integrated



# Motivation (4)

- A lot of user interaction:

# Motivation (4)

- A lot of user interaction:
  - Problem identification

# Motivation (4)

- A lot of user interaction:
  - Problem identification
  - input units & output units

# Motivation (4)

- A lot of user interaction:
  - Problem identification
  - input units & output units
  - not integrated into search process

# Motivation (4)

- A lot of user interaction:
  - Problem identification
  - input units & output units
  - not integrated into search process
- Wouldn't it be nice:

# Motivation (4)

- A lot of user interaction:
  - Problem identification
  - input units & output units
  - not integrated into search process
- Wouldn't it be nice:
  - when searching for 90 $\frac{\text{km}}{\text{h}}$

# Motivation (4)

- A lot of user interaction:
  - Problem identification
  - input units & output units
  - not integrated into search process
- Wouldn't it be nice:
  - when searching for 90 $\frac{\text{km}}{\text{h}}$
  - we also find 25 $\frac{\text{m}}{\text{s}}$

# Motivation (4)

- A lot of user interaction:
  - Problem identification
  - input units & output units
  - not integrated into search process
- Wouldn't it be nice:
  - when searching for 90 $\frac{\text{km}}{\text{h}}$
  - we also find 25 $\frac{\text{m}}{\text{s}}$
- This is the kind of search engine we have built

# Our Approach (1)

- What components do we need for a semantic search engine?

# Our Approach (1)

- What components do we need for a semantic search engine?
  1. A *Unit System* that is aware of the different representations of a QE

# Our Approach (1)

- What components do we need for a semantic search engine?
  1. A *Unit System* that is aware of the different representations of a QE
  2. A *Spotter* that finds representations of QEs inside documents

# Our Approach (1)

- What components do we need for a semantic search engine?
  1. A *Unit System* that is aware of the different representations of a QE
  2. A *Spotter* that finds representations of QEs inside documents
  3. A *Search Algorithm* that given a QE finds all its representations in the system

# Our Approach (1)

- What components do we need for a semantic search engine?
  1. A *Unit System* that is aware of the different representations of a QE
  2. A *Spotter* that finds representations of QEs inside documents
  3. A *Search Algorithm* that given a QE finds all its representations in the system
  4. A *Frontend* that allows queries to be made

# Our Approach (1)

- What components do we need for a semantic search engine?
  1. A *Unit System* that is aware of the different representations of a QE
  2. A *Spotter* that finds representations of QEs inside documents
  3. A *Search Algorithm* that given a QE finds all its representations in the system
  4. A *Frontend* that allows queries to be made
- Spotter is done by *Stiv Sherko*

# Our Approach (2)

- Meta-mathematical model: used to describe structure of mathematics

# Our Approach (2)

- Meta-mathematical model: used to describe structure of mathematics
- *Theory* = List of *Definitions* (= Constants)

# Our Approach (2)

- Meta-mathematical model: used to describe structure of mathematics
- *Theory* = List of *Definitions* (= Constants)
- *Term* = Expression written using definitions from a Theory

# Our Approach (2)

- Meta-mathematical model: used to describe structure of mathematics
- *Theory* = List of *Definitions* (= Constants)
- *Term* = Expression written using definitions from a Theory
- Theories can be related in 2 ways:

# Our Approach (2)

- Meta-mathematical model: used to describe structure of mathematics
- *Theory* = List of *Definitions* (= Constants)
- *Term* = Expression written using definitions from a Theory
- Theories can be related in 2 ways:
  - *Import*s make Constants from one theory available in another

# Our Approach (2)

- Meta-mathematical model: used to describe structure of mathematics
- *Theory* = List of *Definitions* (= Constants)
- *Term* = Expression written using definitions from a Theory
- Theories can be related in 2 ways:
  - *Import*s make Constants from one theory available in another
  - *View* = truth-preserving mapping between theories

# Our Approach (2)

- Meta-mathematical model: used to describe structure of mathematics
- *Theory* = List of *Definitions* (= Constants)
- *Term* = Expression written using definitions from a Theory
- Theories can be related in 2 ways:
  - *Imports* make Constants from one theory available in another
  - *View* = truth-preserving mapping between theories
- Can be displayed in a *Theory Graph*

# Our Approach (2)

- Meta-mathematical model: used to describe structure of mathematics
- *Theory* = List of *Definitions* (= Constants)
- *Term* = Expression written using definitions from a Theory
- Theories can be related in 2 ways:
  - *Imports* make Constants from one theory available in another
  - *View* = truth-preserving mapping between theories
- Can be displayed in a *Theory Graph*
- *MMT* = software that implements these concepts

# Our Approach (2)

- Meta-mathematical model: used to describe structure of mathematics
- *Theory* = List of *Definitions* (= Constants)
- *Term* = Expression written using definitions from a Theory
- Theories can be related in 2 ways:
  - *Imports* make Constants from one theory available in another
  - *View* = truth-preserving mapping between theories
- Can be displayed in a *Theory Graph*
- *MMT* = software that implements these concepts
  - easy to write down theories without programming knowledge

# Our Approach: The Unit System (1)

- Need a *Theory of Quantity Expressions* (QEs)

# Our Approach: The Unit System (1)

- Need a *Theory of Quantity Expressions* (QEs)
- Each quantity has a dimension

# Our Approach: The Unit System (1)

- Need a *Theory of Quantity Expressions* (QEs)
- Each quantity has a dimension
- According to SI there are 7 basic ones:

# Our Approach: The Unit System (1)

- Need a *Theory of Quantity Expressions* (QEs)
- Each quantity has a dimension
- According to SI there are 7 basic ones:
  - length

# Our Approach: The Unit System (1)

- Need a *Theory of Quantity Expressions* (QEs)
- Each quantity has a dimension
- According to SI there are 7 basic ones:
  - length
  - mass

# Our Approach: The Unit System (1)

- Need a *Theory of Quantity Expressions* (QEs)
- Each quantity has a dimension
- According to SI there are 7 basic ones:
  - length
  - mass
  - time

# Our Approach: The Unit System (1)

- Need a *Theory of Quantity Expressions* (QEs)
- Each quantity has a dimension
- According to SI there are 7 basic ones:
  - length
  - mass
  - time
  - electric current

# Our Approach: The Unit System (1)

- Need a *Theory of Quantity Expressions* (QEs)
- Each quantity has a dimension
- According to SI there are 7 basic ones:
  - length
  - mass
  - time
  - electric current
  - temperature

# Our Approach: The Unit System (1)

- Need a *Theory of Quantity Expressions* (QEs)
- Each quantity has a dimension
- According to SI there are 7 basic ones:
  - length
  - mass
  - time
  - electric current
  - temperature
  - luminous intensity

# Our Approach: The Unit System (1)

- Need a *Theory of Quantity Expressions* (QEs)
- Each quantity has a dimension
- According to SI there are 7 basic ones:
  - length
  - mass
  - time
  - electric current
  - temperature
  - luminous intensity
  - amount of substance

# Our Approach: The Unit System (1)

- Need a *Theory of Quantity Expressions* (QEs)
- Each quantity has a dimension
- According to SI there are 7 basic ones:
  - length
  - mass
  - time
  - electric current
  - temperature
  - luminous intensity
  - amount of substance
- but there are also quantities where we just *count*

# Our Approach: The Unit System (1)

- Need a *Theory of Quantity Expressions* (QEs)
- Each quantity has a dimension
- According to SI there are 7 basic ones:
  - length
  - mass
  - time
  - electric current
  - temperature
  - luminous intensity
  - amount of substance
- but there are also quantities where we just *count*
- and *dimensionless quantities* (such as Information)

# Our Approach: The Unit System (1)

- Need a *Theory of Quantity Expressions* (QEs)
- Each quantity has a dimension
- According to SI there are 7 basic ones:
  - length
  - mass
  - time
  - electric current
  - temperature
  - luminous intensity
  - amount of substance
- but there are also quantities where we just *count*
- and *dimensionless quantities* (such as Information)
- so we have 9 basic dimensions

# Our Approach: The Unit System (2)

- we can also multiply these to get new dimensions

# Our Approach: The Unit System (2)

- we can also multiply these to get new dimensions
  - area $=$ length $\cdot$ length

# Our Approach: The Unit System (2)

- we can also multiply these to get new dimensions
  - area $=$ length $\cdot$ length
- similarly we can divide dimensions

# Our Approach: The Unit System (2)

- we can also multiply these to get new dimensions
  - area $=$ length $\cdot$ length
- similarly we can divide dimensions
  - velovity $= \frac{\text{length}}{\text{time}}$

# Our Approach: The Unit System (3) - A Theory of Dimensions

| Dimension | | |
|---|---|---|
| dim | : | type |
| none | : | dim |
| count | : | dim |
| length | : | dim |
| mass | : | dim |
| time | : | dim |
| current | : | dim |
| temperature | : | dim |
| luminous | : | dim |
| amount | : | dim |
| $\cdot$ | : | $\text{dim} \to \text{dim} \to \text{dim}$ |
| $/$ | : | $\text{dim} \to \text{dim} \to \text{dim}$ |

# Our Approach: The Unit System (4)

- Quantity Expressions can be one of

# Our Approach: The Unit System (4)

- Quantity Expressions can be one of
  1. *primitive unit*, such as Meter

# Our Approach: The Unit System (4)

- Quantity Expressions can be one of
  1. *primitive unit*, such as Meter
  2. *Multiplication* of a (real) number with an existing QE, such as 5 Meter

# Our Approach: The Unit System (4)

- Quantity Expressions can be one of
  1. *primitive unit*, such as Meter
  2. *Multiplication* of a (real) number with an existing QE, such as 5 Meter
  3. *Division* of an existing QE by a (non-zero real) number (equivalent to the above)

# Our Approach: The Unit System (4)

- Quantity Expressions can be one of
  1. *primitive unit*, such as Meter
  2. *Multiplication* of a (real) number with an existing QE, such as 5 Meter
  3. *Division* of an existing QE by a (non-zero real) number (equivalent to the above)
  4. *Product* of two existing QEs such as Newton $\cdot$ Second

# Our Approach: The Unit System (4)

- Quantity Expressions can be one of
  1. *primitive unit*, such as Meter
  2. *Multiplication* of a (real) number with an existing QE, such as 5 Meter
  3. *Division* of an existing QE by a (non-zero real) number (equivalent to the above)
  4. *Product* of two existing QEs such as $\text{Newton} \cdot \text{Second}$
  5. *Quotient* of two existing QEs such as $1\ \frac{\text{Meter}}{\text{Second}}$

# Our Approach: The Unit System (4)

- Quantity Expressions can be one of
  1. *primitive unit*, such as Meter
  2. *Multiplication* of a (real) number with an existing QE, such as 5 Meter
  3. *Division* of an existing QE by a (non-zero real) number (equivalent to the above)
  4. *Product* of two existing QEs such as $\text{Newton} \cdot \text{Second}$
  5. *Quotient* of two existing QEs such as $1\ \frac{\text{Meter}}{\text{Second}}$
  6. *Sum* of two existing QEs

# Our Approach: The Unit System (5) - A Theory of Quantity Expressions

| Quantity Expression | | |
|---|---|---|
| import Dimension | | |
| QE | : | $\mathsf{dim} \rightarrow \mathsf{type}$ |
| QENMul | : | $\forall x : \mathsf{dim}.\mathbb{R} \rightarrow \mathsf{QE}(x) \rightarrow \mathsf{QE}(x)$ |
| QENDiv | : | $\forall x : \mathsf{dim}.\mathsf{QE}(x) \rightarrow \mathbb{R} \rightarrow \mathsf{QE}(x)$ |
| QEAdd | : | $\forall x : \mathsf{dim}.\mathsf{QE}(x) \rightarrow \mathsf{QE}(x) \rightarrow \mathsf{QE}(x)$ |
| QEMul | : | $\forall x, y : \mathsf{dim}.\mathsf{QE}(x) \rightarrow \mathsf{QE}(y) \rightarrow \mathsf{QE}(x \cdot y)$ |
| QEDiv | : | $\forall x, y : \mathsf{dim}.\mathsf{QE}(x) \rightarrow \mathsf{QE}(y) \rightarrow \mathsf{QE}\left(\frac{x}{y}\right)$ |

# Our Approach: The Unit System (6)

- we can now easily create theories that define Units, such as a Meter Theory:

# Our Approach: The Unit System (6)

- we can now easily create theories that define Units, such as a Meter Theory:

| Meter | | |
|---|---|---|
| import Quantity Expression | | |
| Meter | : | QE (length) |

# Our Approach: The Unit System (6)

- we can now easily create theories that define Units, such as a Meter Theory:

| Meter | | |
|---|---|---|
| import Quantity Expression | | |
| Meter | : | QE (length) |

- we can also define some non-metric lengths:

# Our Approach: The Unit System (6)

- we can now easily create theories that define Units, such as a Meter Theory:

| Meter |
|---|
| import Quantity Expression |
| Meter : QE (length) |

- we can also define some non-metric lengths:

| Non SI Lengths |
|---|
| import Quantity Expression |
| Thou : QE (length)<br>Foot = QENMul (1000, Thou)<br>Yard = QENMul (3, Foot)<br>Chain = QENMul (22, Yard)<br>Furlong = QENMul (10, Chain)<br>Mile = QENMul (8, Furlong) |

# Our Approach: The Unit System (7)

- need to compare units

# Our Approach: The Unit System (7)

- need to compare units
  - use *Views* ( = truth-preserving mappings between theories)

# Our Approach: The Unit System (7)

- need to compare units
  - use *Views* ( = truth-preserving mappings between theories)
  - For example:

$$\psi = \{\ \mathsf{Thou} \mapsto \mathsf{QENMul}\,(0.0000254, \mathsf{Meter})\ \}$$

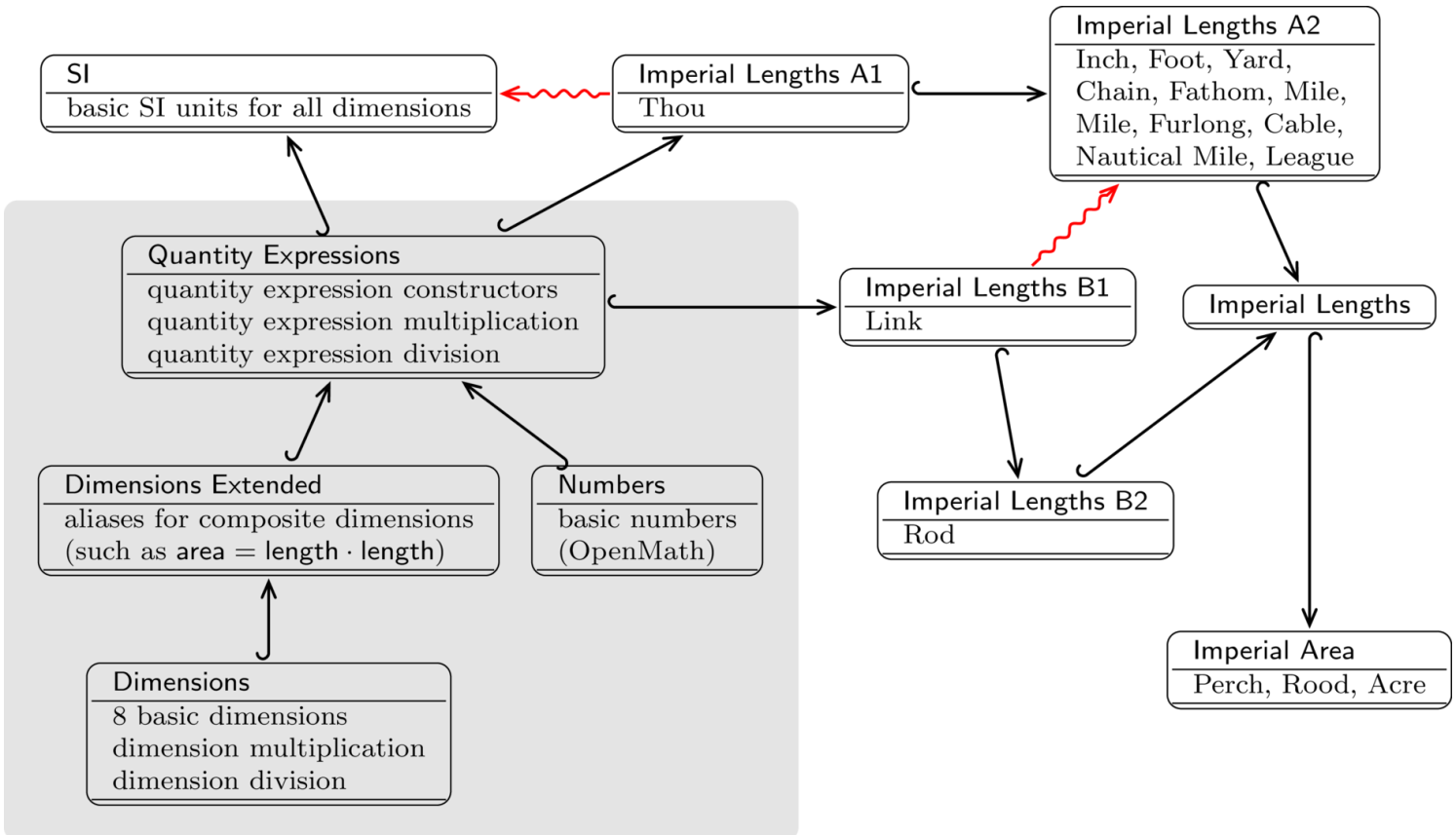
# Our Approach: The Unit System (7)

- need to compare units
  - use *Views* ( = truth-preserving mappings between theories)
  - For example:

$$\psi = \{\ \mathsf{Thou} \mapsto \mathsf{QENMul}\,(0.0000254, \mathsf{Meter})\ \}$$

  - allows conversion

# Our Approach: The Unit System (6) - Part of the unit Theory Graph



# Our Approach: The Search Algorithm (1)

- Let us build a search algorithm

# Our Approach: The Search Algorithm (1)

- Let us build a search algorithm
- We are given a *query* and want to find all equivalent quantity expressions

# Our Approach: The Search Algorithm (1)

- Let us build a search algorithm
- We are given a *query* and want to find all equivalent quantity expressions
- We already have a list of quantity expressions from the spotter

# Our Approach: The Search Algorithm (1)

- Let us build a search algorithm
- We are given a *query* and want to find all equivalent quantity expressions
- We already have a list of quantity expressions from the spotter
- We just need an efficient way to check if two QEs are the same

# Our Approach: The Search Algorithm (1)

- Let us build a search algorithm
- We are given a *query* and want to find all equivalent quantity expressions
- We already have a list of quantity expressions from the spotter
- We just need an efficient way to check if two QEs are the same
- We can just bring QEs to a normal form

# Our Approach: The Search Algorithm (1)

- Let us build a search algorithm
- We are given a *query* and want to find all equivalent quantity expressions
- We already have a list of quantity expressions from the spotter
- We just need an efficient way to check if two QEs are the same
- We can just bring QEs to a normal form
- and then have an efficient index

# Our Approach: The Search Algorithm (2)

- A normal form should consist of two components:

# Our Approach: The Search Algorithm (2)

- A normal form should consist of two components:
- A *scalar* component and a (scalar-free) *unit* component

# Our Approach: The Search Algorithm (2)

- A normal form should consist of two components:
- A *scalar* component and a (scalar-free) *unit* component
- The *unit* component should be in standard units (in our case SI)

# Our Approach: The Search Algorithm (2)

- A normal form should consist of two components:
- A *scalar* component and a (scalar-free) *unit* component
- The *unit* component should be in standard units (in our case SI)
- For this we use 2-step-normalisation

# Our Approach: The Search Algorithm (3)

- Example: Normalise $42\frac{\text{Furlong}}{\text{Fortnight}}$

# Our Approach: The Search Algorithm (3)

- Example: Normalise $42 \frac{\text{Furlong}}{\text{Fortnight}}$
- First, turn all units into standard units by finding an appropriate path in the *theory graph* of units

# Our Approach: The Search Algorithm (3)

- Example: Normalise $42 \frac{\text{Furlong}}{\text{Fortnight}}$
- First, turn all units into standard units by finding an appropriate path in the *theory graph* of units
- Furlong

# Our Approach: The Search Algorithm (3)

- Example: Normalise $42 \frac{\text{Furlong}}{\text{Fortnight}}$
- First, turn all units into standard units by finding an appropriate path in the *theory graph* of units
- Furlong

# Our Approach: The Search Algorithm (3)

- Example: Normalise $42 \frac{\text{Furlong}}{\text{Fortnight}}$
- First, turn all units into standard units by finding an appropriate path in the *theory graph* of units
- Furlong $=$ 10 Chain

# Our Approach: The Search Algorithm (3)

- Example: Normalise $42 \frac{\text{Furlong}}{\text{Fortnight}}$
- First, turn all units into standard units by finding an appropriate path in the *theory graph* of units
- Furlong $=$ 10 Chain $=$ 10 (22 Yard)

# Our Approach: The Search Algorithm (3)

- Example: Normalise $42\frac{\text{Furlong}}{\text{Fortnight}}$
- First, turn all units into standard units by finding an appropriate path in the *theory graph* of units
- $\text{Furlong} = 10\ \text{Chain} = 10\,(22\ \text{Yard}) = \cdots =$
  $10\,(22\,(3\,(12\,(1000\,(0.0000254\ \text{Meter})))))$
- $\text{Fortnight} = (2\,(7\,(24\,(60\,(60\ \text{Second})))))$

# Our Approach: The Search Algorithm (3)

- Example: Normalise $42 \frac{\text{Furlong}}{\text{Fortnight}}$
- First, turn all units into standard units by finding an appropriate path in the *theory graph* of units
- $\text{Furlong} = 10\ \text{Chain} = 10\,(22\ \text{Yard}) = \cdots =$ $10\,(22\,(3\,(12\,(1000\,(0.0000254\ \text{Meter})))))$
- $\text{Fortnight} = (2\,(7\,(24\,(60\,(60\ \text{Second})))))$
- Substitute this back into the original expression

# Our Approach: The Search Algorithm (3)

- Example: Normalise $42\frac{\text{Furlong}}{\text{Fortnight}}$
- First, turn all units into standard units by finding an appropriate path in the *theory graph* of units
- Furlong $=$ 10 Chain $=$ 10 (22 Yard) $= \cdots =$ 10 (22 (3 (12 (1000 (0.0000254 Meter)))))
- Fortnight $=$ (2 (7 (24 (60 (60 Second)))))
- Substitute this back into the original expression
- $42\frac{10(22(3(1000(0.0000254\ \text{Meter}))))}{2(7(24(60(60\ \text{Second}))))}$

# Our Approach: The Search Algorithm (3)

- Example: Normalise $42\frac{\text{Furlong}}{\text{Fortnight}}$
- First, turn all units into standard units by finding an appropriate path in the *theory graph* of units
- Furlong $=$ 10 Chain $=$ 10 (22 Yard) $= \cdots =$ 10 (22 (3 (12 (1000 (0.0000254 Meter)))))
- Fortnight $=$ (2 (7 (24 (60 (60 Second)))))
- Substitute this back into the original expression
- $42\frac{10(22(3(1000(0.0000254\ \text{Meter}))))}{2(7(24(60(60\ \text{Second}))))}$
- Then extract the *scalar* component and compute it:

# Our Approach: The Search Algorithm (3)

- Example: Normalise $42\frac{\text{Furlong}}{\text{Fortnight}}$
- First, turn all units into standard units by finding an appropriate path in the *theory graph* of units
- $\text{Furlong} = 10\ \text{Chain} = 10\,(22\ \text{Yard}) = \cdots =$ $10\,(22\,(3\,(12\,(1000\,(0.0000254\ \text{Meter})))))$
- $\text{Fortnight} = (2\,(7\,(24\,(60\,(60\ \text{Second})))))$
- Substitute this back into the original expression
- $42\frac{10(22(3(1000(0.0000254\ \text{Meter}))))}{2(7(24(60(60\ \text{Second}))))}$
- Then extract the *scalar* component and compute it:
- $42\frac{10(22(3(12(1000(0.0000254))))))}{2(7(24(60(60))))} = 0.006985$

# Our Approach: The Search Algorithm (3)

- Example: Normalise $42\frac{\text{Furlong}}{\text{Fortnight}}$
- First, turn all units into standard units by finding an appropriate path in the *theory graph* of units
- Furlong $= 10$ Chain $= 10\,(22$ Yard$) = \cdots =$ $10\,(22\,(3\,(12\,(1000\,(0.0000254$ Meter$)))))$
- Fortnight $= (2\,(7\,(24\,(60\,(60$ Second$)))))$
- Substitute this back into the original expression
- $42\frac{10(22(3(1000(0.0000254\ \text{Meter}))))}{2(7(24(60(60\ \text{Second}))))}$
- Then extract the *scalar* component and compute it:
- $42\frac{10(22(3(12(1000(0.0000254)))))}{2(7(24(60(60))))} = 0.006985$
- Continue by extracting the *unit* component: $\frac{\text{Meter}}{\text{Second}}$

# Our Approach: The Search Algorithm (3)

- Example: Normalise $42\frac{\text{Furlong}}{\text{Fortnight}}$
- First, turn all units into standard units by finding an appropriate path in the *theory graph* of units
- $\text{Furlong} = 10\ \text{Chain} = 10\,(22\ \text{Yard}) = \cdots =$ $10\,(22\,(3\,(12\,(1000\,(0.0000254\ \text{Meter})))))$
- $\text{Fortnight} = (2\,(7\,(24\,(60\,(60\ \text{Second})))))$
- Substitute this back into the original expression
- $42\frac{10(22(3(1000(0.0000254\ \text{Meter}))))}{2(7(24(60(60\ \text{Second}))))}$
- Then extract the *scalar* component and compute it:
- $42\frac{10(22(3(12(1000(0.0000254))))))}{2(7(24(60(60))))} = 0.006985$
- Continue by extracting the *unit* component: $\frac{\text{Meter}}{\text{Second}}$
- Finally multiply these components to get the standard form:

# Our Approach: The Search Algorithm (3)

- Example: Normalise $42\,\frac{\text{Furlong}}{\text{Fortnight}}$
- First, turn all units into standard units by finding an appropriate path in the *theory graph* of units
- $\text{Furlong} = 10\ \text{Chain} = 10\,(22\ \text{Yard}) = \cdots =$ $10\,(22\,(3\,(12\,(1000\,(0.0000254\ \text{Meter})))))$
- $\text{Fortnight} = (2\,(7\,(24\,(60\,(60\ \text{Second})))))$
- Substitute this back into the original expression
- $42\,\frac{10(22(3(1000(0.0000254\ \text{Meter}))))}{2(7(24(60(60\ \text{Second}))))}$
- Then extract the *scalar* component and compute it:
- $42\,\frac{10(22(3(12(1000(0.0000254))))))}{2(7(24(60(60))))} = 0.006985$
- Continue by extracting the *unit* component: $\frac{\text{Meter}}{\text{Second}}$
- Finally multiply these components to get the standard form:
- $0.006985\ \frac{\text{Meter}}{\text{Second}}$

# Our Approach: The Search Algorithm (4)

- We can then compare the spotted QEs with the query via directly comparing normal forms

# Our Approach: The Search Algorithm (4)

- We can then compare the spotted QEs with the query via directly comparing normal forms
- To save time, we *cache* the normal form of each unit

# Our Approach: The Search Algorithm (4)

- We can then compare the spotted QEs with the query via directly comparing normal forms
- To save time, we *cache* the normal form of each unit
- We can also *cache* the normal forms of the QEs found by the spotter

# Our Approach: The Search Algorithm (4)

- We can then compare the spotted QEs with the query via directly comparing normal forms
- To save time, we *cache* the normal form of each unit
- We can also *cache* the normal forms of the QEs found by the spotter
- Important: We choose SI units for the standard form

# Our Approach: The Search Algorithm (4)

- We can then compare the spotted QEs with the query via directly comparing normal forms
- To save time, we *cache* the normal form of each unit
- We can also *cache* the normal forms of the QEs found by the spotter
- Important: We choose SI units for the standard form
- This is not required. We could also choose to use imperial units as a normal form

# Our Approach: The Search Algorithm (4)

- We can then compare the spotted QEs with the query via directly comparing normal forms
- To save time, we *cache* the normal form of each unit
- We can also *cache* the normal forms of the QEs found by the spotter
- Important: We choose SI units for the standard form
- This is not required. We could also choose to use imperial units as a normal form
- Our unit graph is flexible enough so that we can actually do that

# Conclusion: The Implementation

- We have the following implemented components:

# Conclusion: The Implementation

- We have the following implemented components:
- The frontend, written in HTML, CSS, JavaScript

# Conclusion: The Implementation

- We have the following implemented components:
- The frontend, written in HTML, CSS, JavaScript
- when queried, this sends a QE to the backend

# Conclusion: The Implementation

- We have the following implemented components:
- The frontend, written in HTML, CSS, JavaScript
- when queried, this sends a QE to the backend
- The backend, written in scala, uses MMT to normalise this expression

# Conclusion: The Implementation

- We have the following implemented components:
- The frontend, written in HTML, CSS, JavaScript
- when queried, this sends a QE to the backend
- The backend, written in scala, uses MMT to normalise this expression
- and then searches the harvests (provided by Stiv's Spotter)

# Conclusion: The Implementation

- We have the following implemented components:
- The frontend, written in HTML, CSS, JavaScript
- when queried, this sends a QE to the backend
- The backend, written in scala, uses MMT to normalise this expression
- and then searches the harvests (provided by Stiv's Spotter)
- Finally the frontend displays a list of results

# Conclusion: The Implementation (2)

- The unit Graph are extensible

# Conclusion: The Implementation (2)

- The unit Graph are extensible
- The user does not need to think about what units are inside the documents

# Conclusion: The Implementation (2)

- The unit Graph are extensible
- The user does not need to think about what units are inside the documents
- Time for a demo (if there is still time)

# Time for Questions

## Thank You For Listening!

Image sources:

- http://www.gettingaroundgermany.info/g_imgs/z274.gif
- http://upload.wikimedia.org/wikipedia/commons/thumb/1/19/Mars_Climate_Orbiter_2.jpg/528px-Mars_Climate_Orbiter_2.jpg