Exploring the single-brain barrier

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Outline

• Motivation
• Our approach
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Motivation

• “one-brain barrier” [1]
  – Metaphor: relevant knowledge to conduct math research needs to be co-located in one brain

• Goals of our contribution to NTCIR12:
  – Create a point of reference w.r.t. to this barrier for a trained mathematician
  – Compare the performance of a human to MIR systems and analyse characteristic strengths and weaknesses
  – Derive insights to improve MIR systems
  – Combine the relevant results of the human and the MIR systems to create a gold standard
Our approach

1. Initial NTCIR-12 Math Wikipedia Task
2. Pooling of Results
3. Scoring by Assessors
4. Filtering for Most Relevant Results
5. Generation of: Gold Standard & Duplicates

Computer Driven Approaches

Brain System
Our submission

• 38 manually picked and ranked formulae for 29 of the 30 topics

• We used human intuition to estimate the information need that the topic shall express.
  – We submitted 1-2 results per topic that we consider to fulfil the information need.
  – MIR systems submitted 1,000 results.

• Some results we considered relevant were not included in the test corpus.
**Example result**

- **Query**
  - Difference between $\log_{10} x_1$ and $\log x_1$

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**Common logarithm**

In mathematics, the **common logarithm** is the logarithm with base 10. It is also known as the **decadic logarithm** and also as the **decimal logarithm**, named after its base, or **Briggsian logarithm**, after Henry Briggs, an English mathematician who pioneered its use, as well as "standard logarithm". It is indicated by $\log_{10}(x)$, or sometimes $\text{Log}(x)$ with a capital L (however, this notation is ambiguous since it can also mean the complex natural logarithmic multi-valued function). On calculators it is usually designated by the symbol $\log$, and the value of $\log_{10} 10$ is exactly 1.
Example result

• Query
  - Prove \((f \circ g)' = (f' \circ g) \cdot g'\)

Chain rule

In calculus, the \textbf{chain rule} is a \textit{formula} for computing the \textit{derivative} of the \textit{composition} of two or more \textit{functions}. That is, if \(f\) and \(g\) are functions, then the chain rule expresses the derivative of their composition \(f \circ g\) (the function which maps \(x\) to \(f(g(x))\)) in terms of the derivatives of \(f\) and \(g\) and the \textit{product of functions} as follows:

\[
(f \circ g)' = (f' \circ g) \cdot g'.
\]

This can be written more explicitly in terms of the variable. Let \(F = f \circ g\), or equivalently, \(F(x) = f(g(x))\) for all \(x\). Then one can also write

\[
F'(x) = f'(g(x))g'(x).
\]
Overall assessments

Number of pages judged (grouped by score)

Topic

28/10/2016
Assessment of our results

![Graph showing relevance scores and standard deviations for different topics. The graph compares average scores (with standard deviation) and individual scores. The x-axis represents topics numbered 1 to 30, and the y-axis represents relevance scores ranging from -1 to 4.]
Derived gold standard

• Included 30 relevant results that we missed, but MIR systems found

• Reduced gold standard to 28 topics and result set to manageable size for developers

• Grouped topics into 6 categories
  • Definition Look-up, Explanation, Proof, Application, Computation Assistance, General Formula Search
Conclusion

• Strengths of MIR systems:
  – Definition lookup queries
  – Application lookup

• Weaknesses of MIR systems
  – Low precision
  – No unified query language to specify query type

• Gold standard dataset can help to develop a math-aware search engine for Wikipedia
Future work

• Use the derived gold standard dataset and Mathematical Language Processing technology to develop our math search engine for Wikipedia

• Include capabilities to describe the type information need:
  1. Definition look-up
  2. Explanation look-up
  3. Proof look-up
  4. Application look-up
  5. Computation assistance
  6. General formula search
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