CIS 640: Writing Up Research Results

Theory
Algorithms
Experiments

Some quotes about scientific writing from famous computer scientists

**Leslie Lamport:** “Bad thinking never produces good writing.” (Good writing promotes good thinking ...)

**Donald Knuth:** “Word-smithing is a much greater percentage of what I am supposed to be doing in life than I would ever have thought.”

Hints on Good Mathematical Writing
(David Goss, Ohio State; John Lee, UW)

https://people.math.osu.edu/goss.3/hint.pdf

- Overall:
  - Have mercy on the reader, reviewers, editor/publisher.
  - Avoid giving the reader the impression that the subject matter can only be mastered with great pain.

Good Mathematical Writing

- Use proper English.
  - Each mathematical symbol or formula should have a definite grammatical symbol as part of a sentence.
  - Use proper English punctuation with mathematical formulas

  \[ \text{If } x > 5 \text{, we see that } x^2 + x \text{ must be greater than 5.} \]

- Proofs
  - Include enough detail to make the theorem believable and leave the reader with the confidence they can fill in the details
  - End proofs consistently with QED or Q. E. D. or □.
  - Use consistent formatting, indentation, fonts, etc.

Good Mathematical Writing (Goss and Zobel)

- Notation
  - Use subscripts rather than brackets \( x_i \) instead of \( x[i] \).
  - Be clear with quantifiers.
  - Avoid abbreviations such as s.t., iff, w.o.l.g.
  - Use “big O” notation correctly
  - Do not begin a sentence with a math symbol.
Good Mathematical Writing
(Goss and Zobel)

• Insert English words to break up in-line mathematical formulas.
• Avoid writing two in-line formulas separated only by a comma or other punctuation mark, because they will look like one long formula. For example, the sentence "If $x > 0$, then $x > a$" can become confusing. It would be better to read if a word were inserted between the two formulas, as in "If $x > 0$, then $x^a > a$.”
• It is better to write “... we prove that $\frac{\Omega(2n)}{\pi^2}$ belongs to $Q$" (or “is rational”) instead of “... we prove $\frac{\Omega(2n)}{\pi^2} \in Q$.”

Mathematics vs. Algorithms
(Theory vs. Systems)

– Use of the terms constant, linear, logarithmic, exponential
– Use of “big $O$” notation.

Complexity Results
(Theory vs Systems)


For the formal definition, suppose $f(x)$ and $g(x)$ are two functions defined on some subset of the real numbers. We write:

$f(x) = O(g(x))$

(or $f(x) \preceq g(x)$ for $x \to \infty$ to be more precise) if and only if there exist constants $N$ and $C$ such that

$|f(x)| \leq C \cdot |g(x)|$ for all $x \geq N$.

Intuitively, this means that $f$ does not grow faster than $g$.

Complexity Results
(Theory vs. Systems)


<table>
<thead>
<tr>
<th>Notation</th>
<th>Definition</th>
<th>Analogy</th>
</tr>
</thead>
<tbody>
<tr>
<td>$f(x) = O(g(x))$</td>
<td>see above</td>
<td>$&lt; x$</td>
</tr>
<tr>
<td>$f(x) = \omega(g(x))$</td>
<td>see above</td>
<td>$&gt;$</td>
</tr>
<tr>
<td>$f(x) = \Theta(g(x))$</td>
<td>$g(x) = \Omega(f(x))$</td>
<td>$\approx x$</td>
</tr>
<tr>
<td>$f(x) = o(g(x))$</td>
<td>$g(x) = \omega(f(x))$</td>
<td>$&lt; x$</td>
</tr>
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<td>$&gt; x$</td>
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</tbody>
</table>

The notations $\Omega$ and $o$ are often used in computer science; the lowercase $\omega$ is common in mathematics but rare in computer science. The lowercase $o$ is rarely used.

Complexity Results
(Theory vs. Systems)

Use the terms constant, linear, logarithmic, and exponential carefully.

<table>
<thead>
<tr>
<th>notation</th>
<th>name</th>
</tr>
</thead>
<tbody>
<tr>
<td>O(1)</td>
<td>constant</td>
</tr>
<tr>
<td>O($\log(n)$)</td>
<td>logarithmic</td>
</tr>
<tr>
<td>O($\log(n)^2$)</td>
<td>polylogarithmic</td>
</tr>
<tr>
<td>O($n$)</td>
<td>linear</td>
</tr>
<tr>
<td>O($n^2$)</td>
<td>quadratic</td>
</tr>
<tr>
<td>O($n^2$)</td>
<td>polynomial</td>
</tr>
<tr>
<td>O($e^n$)</td>
<td>exponential</td>
</tr>
</tbody>
</table>
Ten Simple Rules for Mathematical Writing (D. Bertsekas, MIT)

- Organize in segments.
- Write segments linearly. Depth first order usually better.
- Hierarchical order like subroutines in a program.
- Use consistent mathematical notation.
- Use consistent presentation of results.

Avoid unnecessary notation:
- BAD: Let $X$ be a compact subset of a space $Y$. If $f$ is a continuous real-valued function over $X$, it attains a minimum over $X$.
- GOOD: A continuous real-valued function attains a minimum over a compact set.

Sometimes the authors of systems papers introduce formalisms and mathematical definitions that are not used later in the paper (perhaps to make their work appear erudite.)

Writing about Algorithms

Description of the algorithm may include:
- Steps that make up the algorithm
- Input, output, internal data structures
- Scope and limitations
- Properties needed to prove correctness (pre-conditions, post conditions, loop invariants)
- Proof or demonstration of correctness
- Complexity analysis (space and time)
- Experiments confirming theoretical results

Writing about Experiments

Writing about the experimental setup:
- Goals of the experiments
- Assumptions made
- Parameters
- Environment of the experiments
  - Experimental platform
  - Baseline comparator(s)
  - Benchmark suites
Writing about Experiments

Writing about the results:
• Analyze results in a way that makes them interesting.
• Explain their significance.
• Select and discuss typical results.
• Select and discuss interesting results.
• Discuss anomalies.

Writing about Experiments

Writing about a figure or graph(s):
• Do more than simply state what is in the figure.
• Use evaluative language.
  Ex: As can be seen in Fig. 1, the two curves are very similar. (As can be seen in Fig. 1, the two curves are dramatically different.)
• Point out and explain interesting phenomena.
  Ex: Although the mean concentrations were in line with those of Figo et. Al., a striking difference was noted during each of the three peak hours (see Fig 2.)

A template for writing about algorithms/software tools
(Science Research Writing by Hilary Glasman-Deal)
1. Provide general introduction and overview of the algorithm/software tool.
2. Restate the purpose of the work.
3. Describe the features of the algorithm/tool.
4. Provide specific and precise details.
5. Justify choices made.
6. Highlight unique contributions of the alg/tool.
7. Relate algorithm/tool to other similar.

A template for writing about research methodology
(Science Research Writing by Hilary Glasman-Deal)
1. Provide general introduction and overview of material/methods.
2. Restate the purpose of the work.
3. Give the source of materials/equipment used.
4. Provide specific and precise details about materials and methods.
5. Justify choices made.
6. Relate materials/methods to other studies.
7. Indicate where problems occurred.

A template for writing about research results
(Science Research Writing by Hilary Glasman-Deal)
1. Revisit the research goals.
2. Revisit and expand the methodology.
3. Give general overview of the results.
4. Invite reader to view results.
5. Describe key results in detail (with or without visualizations).
6. Compare results with expected results or predictions.
7. Compare results with results from other research.
8. Discuss problems with results.
9. Discuss implications of results.

In-class Exercise

Examine several excellent and one poor research paper:
• To what extent do these papers adhere follow the templates proposed by Glasman-Deal.
• Look for examples of good (or poor) practices suggested by Goss, Lee, and Zobel.
**Sparrow: Distributed Low Latency Scheduling**
(by Ousterhout, Wendell, Zaharia, Stoica, UC Berkeley)


Kay Ousterhout is a Ph.D. student at UC Berkeley.

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**Whole Home Gesture Recognition Using Wireless Signals**
by Q. Pu, S. Gupta, S. Gollakota, and S. Patel, UW


(Gollakota won the ACM Best Dissertation Award in 2012)

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They Can Hear Your Heartbeats: Non-Invasive Security for Implantable Medical Devices
(by S. Gollakota, H. Hassanieh, B. Ransford, D. Katabi, K. Fu)


(Best paper SIGCOMM 2011)

Dina Katabi won the ACM Best Dissertation Award in 2013. She also won a MacArthur Fellowship in 2013.