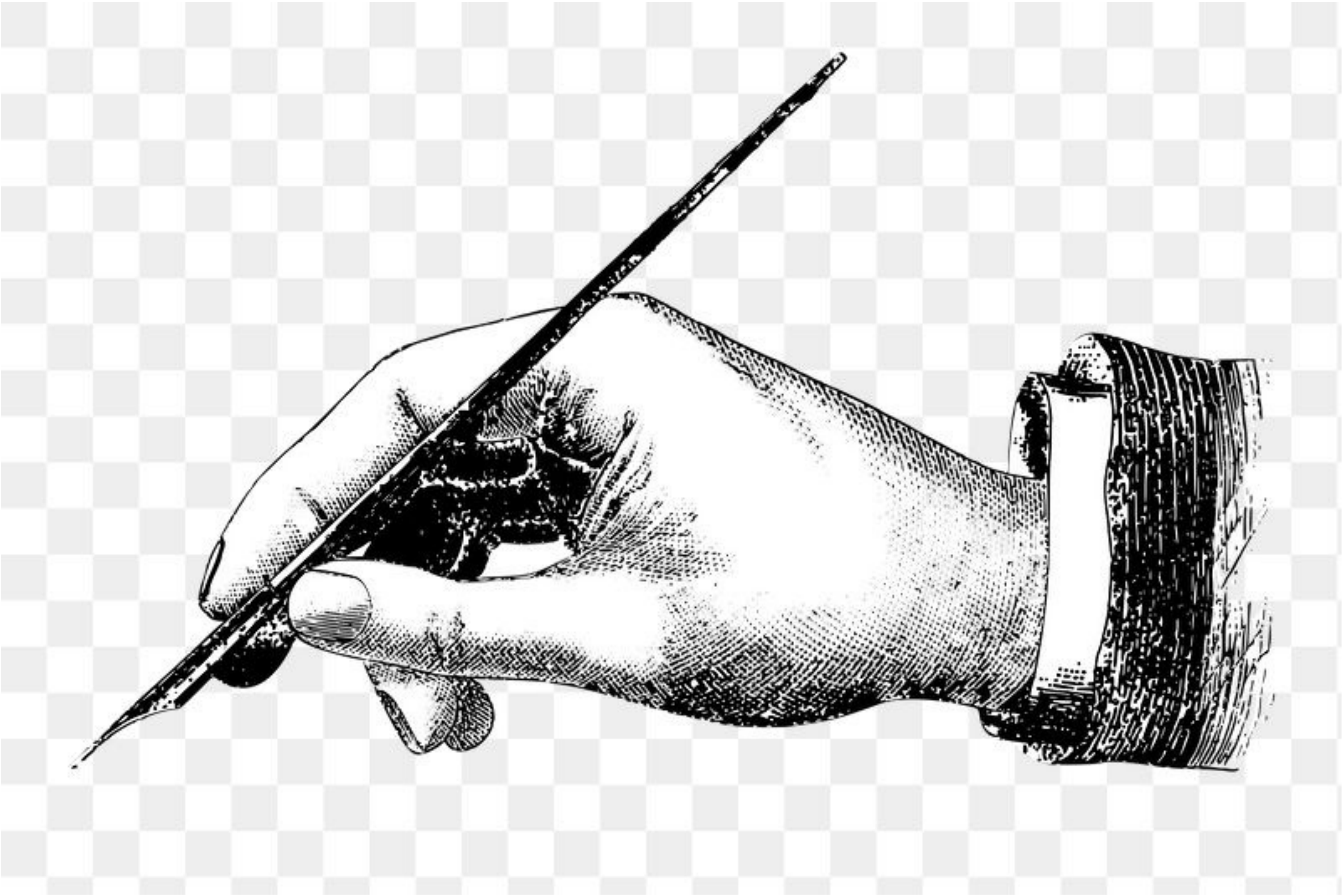
How to Write a Technical Paper



Michael Hicks, University of Maryland & Amazon

simon.peytonjones.org/great-research-paper/

How to Write a Great Research Paper

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Introduction

This talk offers seven simple, concrete suggestions for how to improve your research papers. You may also find my talks on how to write a great research proposal and how to give a great research talk useful.

- Powerpoint slides of the talk: PDF PPT (you should feel free to repurpose these slides for your own use as long as you acknowledge ownership)

How to write a great research paper

Simon Peyton Jones

with amendments/additions by
Mike Hicks, UMD and Amazon

Microsoft ← SPJ used to work here

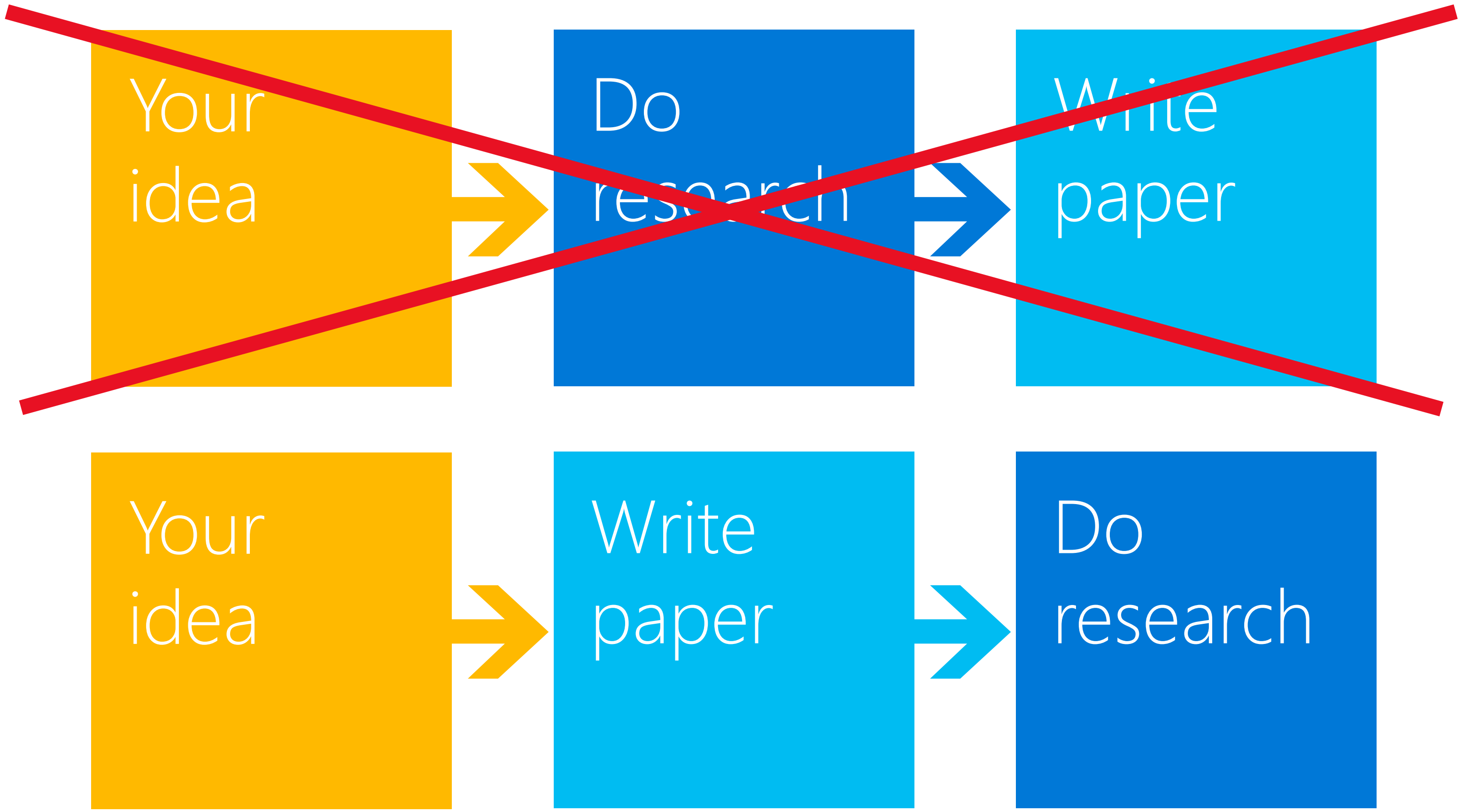
Seven simple, actionable suggestions

that will make your papers better.

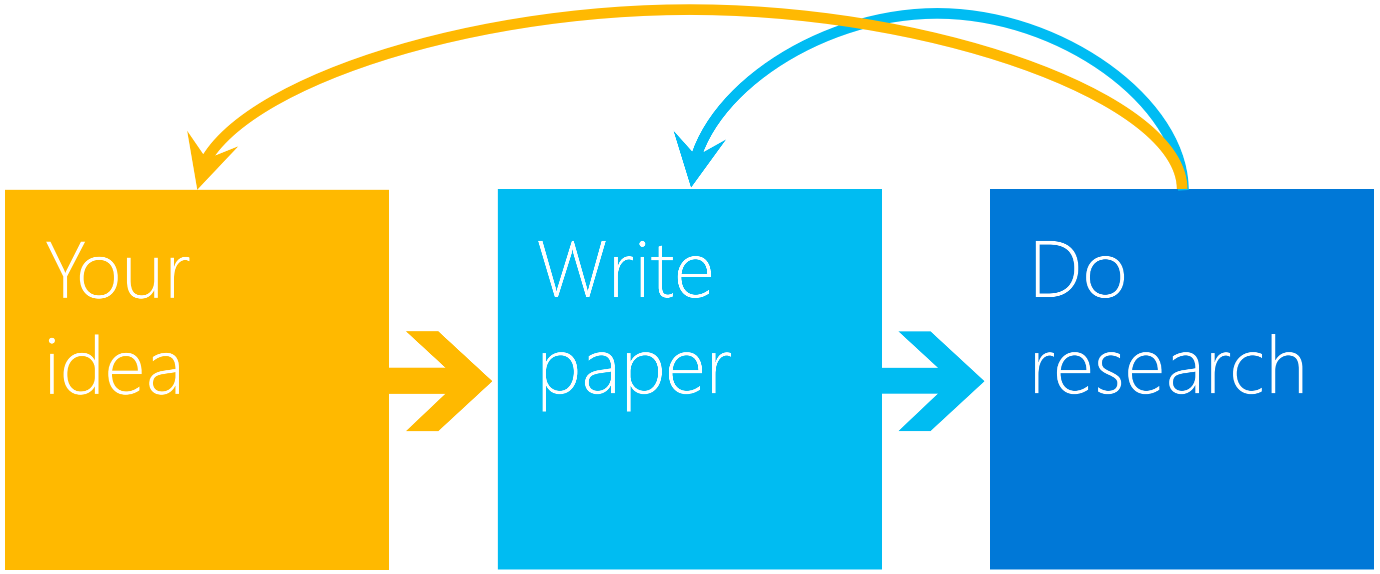
1. Don’t wait: write

Writing papers: model 1

Writing papers: (provocative) model 2



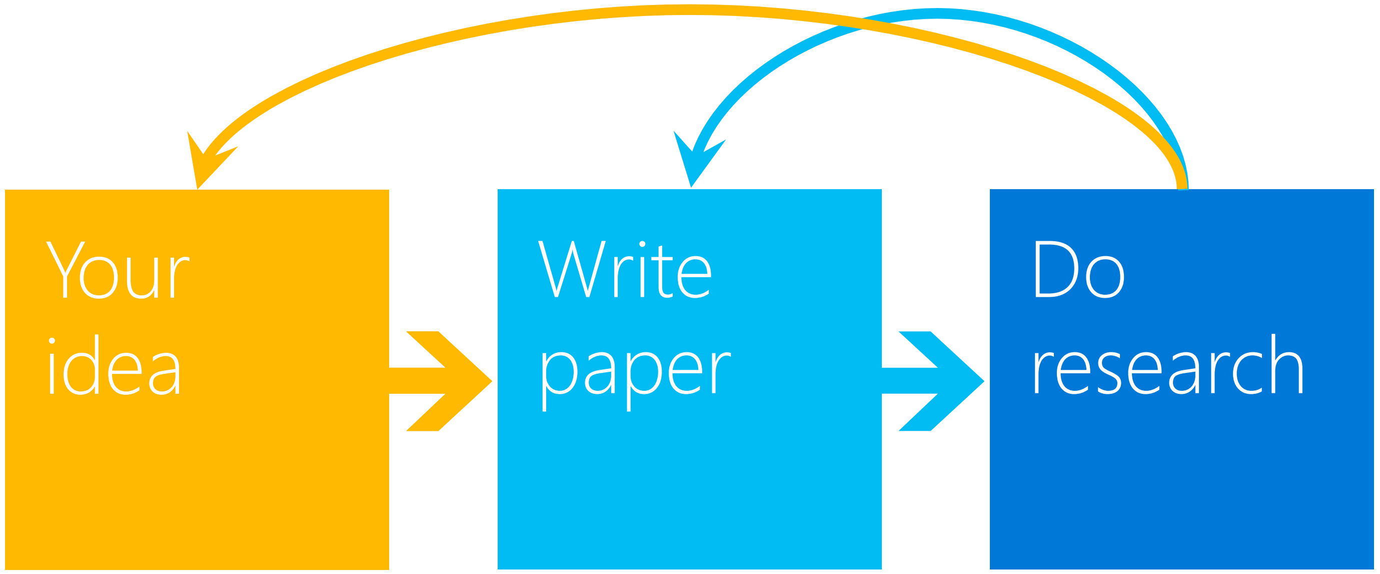
Writing papers: (provocative) model 2



- Forces us to be clear, focused
- Crystallises what we don't understand
- Opens the way to dialogue with others: reality check, critique, and collaboration

Updated by mwh, 6/12/22

Writing papers: (provocative) model 2



Writing papers is a primary mechanism for doing research (not just for reporting it)

Updated by mwh, 6/12/22

2. Identify your key idea

Your goal: to convey a useful and re-usable idea

- You want to infect the mind of your reader with your idea, like a virus
- Papers are far more durable than programs (think Mozart)

The greatest ideas are (literally) worthless if you keep them to yourself

Do not be intimidated

Fallacy

You need to have a fantastic idea before you can write a paper. (Everyone else seems to.)

Write a paper, and give a talk, about any idea, no matter how weedy and insignificant it may seem to you

It’s a process

Writing the paper is how you develop the idea in the first place

- It usually turns out to be more interesting and challenging that it seemed at first

Writing about it also helps you

- Understand the problem space better
  - Better to solve a real problem than to design a solution looking for one
- Get feedback

Added by mwh, 11/21/07

Paper writing is teaching

- It is useful to think that you are teaching your reader your idea
  - What you did
  - Why it's important
  - How it works
- Well-written papers contribute more than just their described results
  - Readers understand the topic better

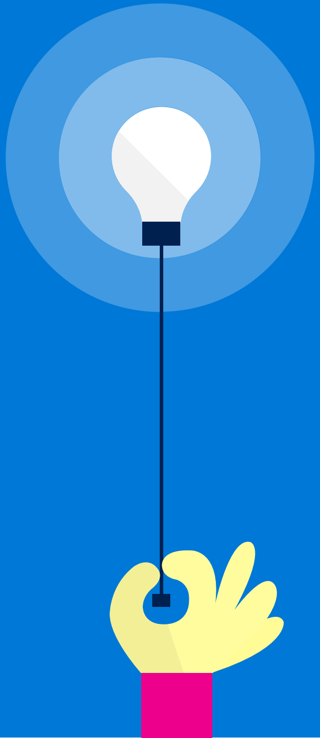
Added by mwh, 11/21/07

The idea

Idea:
A re-usable insight, useful to the reader

- Your paper should have just one "ping": one clear, sharp idea
- You may not know exactly what the ping is when you start writing; but you must know when you finish
- If you have lots of ideas, write lots of papers

Can you hear the "ping"?



- Many papers contain good ideas, but do not distil what they are.
- Make certain that the reader is in no doubt what the idea is. Be 100% explicit:
  - "The main idea of this paper is...."
  - "In this section we present the main contributions of the paper."

Thanks to Joe Touch for "one ping"

3. Tell a story

Your narrative flow

Imagine you are explaining at a whiteboard

- Here is a problem
- It's an interesting problem
- It's an unsolved problem
- Here is my idea
- My idea works (details, data)
- Here's how my idea compares to other people's approaches

Define your reader

- A whiteboard discussion is for a particular person. When writing a paper, your readers are not in front of you. So: What can you *assume* they know?
  - Technical methods and results
  - Preconceptions/attitude
  - Interests
- As a proxy, consider the intended venue
  - Who is on the PC? What work do they do?
  - What are the topics and assumptions of papers previously published here?

Added by mwh, 11/21/07

Structure (conference paper)

- Title (1000 readers)
- Abstract (4 sentences, 100 readers)
- Introduction (1 page, 100 readers)
- The problem (1 page, 10 readers)
- My idea (2 pages, 10 readers)
- The details (5 pages, 3 readers)
- Related work (1-2 pages, 10 readers)
- Conclusions and further work (0.5 pages, 100 readers)

4. Nail your contributions to the mast

The introduction (1 page)

- Describe the problem

  What is the broader context?

  What is the particular problem?

  - Why is it interesting?

- State your contributions

  What is new? (novelty)

  Why is it useful? (features of your solution)

  How do you know? (evaluation)

Assume reader is general attendee of target conference

Amended by mwh, 11/21/07

Describe the problem

1 Introduction

There are two basic ways to implement function application in a higher-order language, when the function is unknown: the *push/enter* model or the *eval/apply* model [11]. To illustrate the difference, consider the higher-order function **zipWith**, which zips together two lists, using a function **k** to combine corresponding list elements:

```
zipWith :: (a->b->c) -> [a] -> [b] -> [c]
zipWith k []     []     = []
zipWith k (x:xs) (y:ys) = k x y : zipWith xs ys
```

Here **k** is an *unknown function*, passed as an argument; global flow analysis aside, the compiler does not know what function **k** is bound to. How should the compiler deal with the call **k x y** in the body of **zipWith**? It can't blithely apply **k** to two arguments, because **k** might in reality take just one argument and compute for a while before returning a function that consumes the next argument; or **k** might take three arguments, so that the result of the **zipWith** is a list of functions.

Use an example to introduce the problem

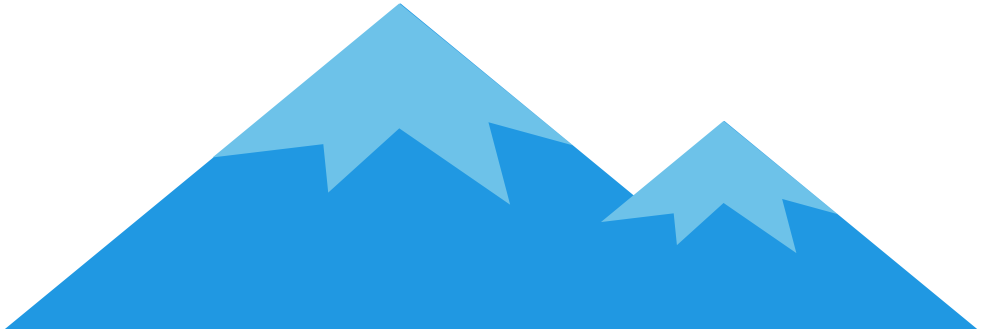
Molehills not mountains

Example: “Computer programs often have bugs. It is very important to eliminate these bugs [1,2]. Many researchers have tried [3,4,5,6]. It really is very important.”

Yawn!

Example: “Consider this program, which has an interesting bug. <brief description>. We will show an automatic technique for identifying and removing such bugs”

Cool!



State your contributions

- Write the list of contributions first
- The list of contributions drives the entire paper: the paper substantiates the claims you have made
- Reader thinks "gosh, if they can really deliver this, that's be exciting; I'd better read on"

State your contributions

Do not leave the reader to guess what your contributions are!

Which of the two is best in practice? The trouble is that the evaluation model has a pervasive effect on the implementation, so it is too much work to implement both and pick the best. Historically, compilers for strict languages (using call-by-value) have tended to use eval/apply, while those for lazy languages (using call-by-need) have often used push/enter, but this is 90% historical accident — either approach will work in both settings. In practice, implementors choose one of the two approaches based on a qualitative assessment of the trade-offs. In this paper we put the choice on a firmer basis:

- We explain precisely what the two models are, in a common notational framework (Section 4). Surprisingly, this has not been done before.
- The choice of evaluation model affects many other design choices in subtle but pervasive ways. We identify and discuss these effects in Sections 5 and 6, and contrast them in Section 7. There are lots of nitty-gritty details here, for which we make no apology — they were far from obvious to us, and articulating these details is one of our main contributions.

In terms of its impact on compiler and run-time system complexity, eval/apply seems decisively superior, principally because push/enter requires a stack like no other: stack-walking

Bulleted list of contributions

Contributions should be refutable

No!	Yes!
We describe the WizWoz system. It is really cool.	We give the syntax and semantics of a language that supports concurrent processes (Section 3). Its innovative features are...
We study its properties	We prove that the type system is sound, and that type checking is decidable (Section 4)
We have used WizWoz in practice	We have built a GUI toolkit in WizWoz, and used it to implement a text editor (Section 5). The result is half the length of the Java version.

Evidence

- Your introduction makes claims
- The body of the paper provides evidence to support each claim
- Check each claim in the introduction, identify the evidence, and forward-reference it from the claim
- "Evidence" can be: analysis and comparison, theorems, measurements, case studies

No “rest of this paper is...”

- Not:
  “The rest of this paper is structured as follows. Section 2 introduces the problem. Section 3 ...Finally, Section 8 concludes”.
- Instead, use forward references from the narrative in the introduction. The introduction (including the contributions) should survey the whole paper, and therefore forward reference every important part.

A longer introduction?

- The introduction can be viewed a capsule of the entire paper
  - The context, the problem, your idea, and its evaluation
- You could shorten or avoid the *problem* and *idea* sections and have a longer intro
  - Make part of the intro (subsections)
  - But beware of taking too long to get to the point; reader will get frustrated

- Title (1000 readers)
- Abstract (4 sentences, 100 readers)
- Introduction (1 page, 100 readers)
- ~~The problem (1 page, 10 readers)~~
- ~~My idea (2 pages, 10 readers)~~
- The details (5 pages, 3 readers)
- Related work (1-2 pages, 10 readers)
- Conclusions and further work (0.5 pages, 100 readers)

Added by mwh, 11/21/07

The abstract (4 sentences)

- Should be brief, not assume too much, and highlight items of importance
- Four sentences [Kent Beck]
  - State the problem
  - Say why it's an interesting problem
  - Say what your solution achieves
  - Say what follows from your solution
- I usually write the abstract second-to-last
  - **Last is the conclusions!**

Amended by mwh, 11/21/07

Example

1) Many papers are badly written and hard to understand
2) This is a pity, because their good ideas may go unappreciated
3) Following simple guidelines can dramatically improve the quality of your papers
4) Your work will be used more, and the feedback you get from others will in turn improve your research

Deviating from the ideal

- The abstract can be longer **if there is a purpose relevant to your reader**, e.g.,
  - Expand on the problem context
  - Brief recap of prior results
  - Indicate several results (e.g., one sentence per result)
- Remember, the goal is to get the reader to read the introduction …

Amended by mwh, 11/21/07

Finding your (peer) reviewers

- The abstract has a very specific purpose in the peer review process: Finding the right reviewers
- Reviewers will read abstracts to bid on papers to review; how to signal the right reviewers to select your paper?
  - Problem domain
  - Techniques used
  - Results achieved

Amended by mwh, 11/21/07

5. Related work: later

Structure

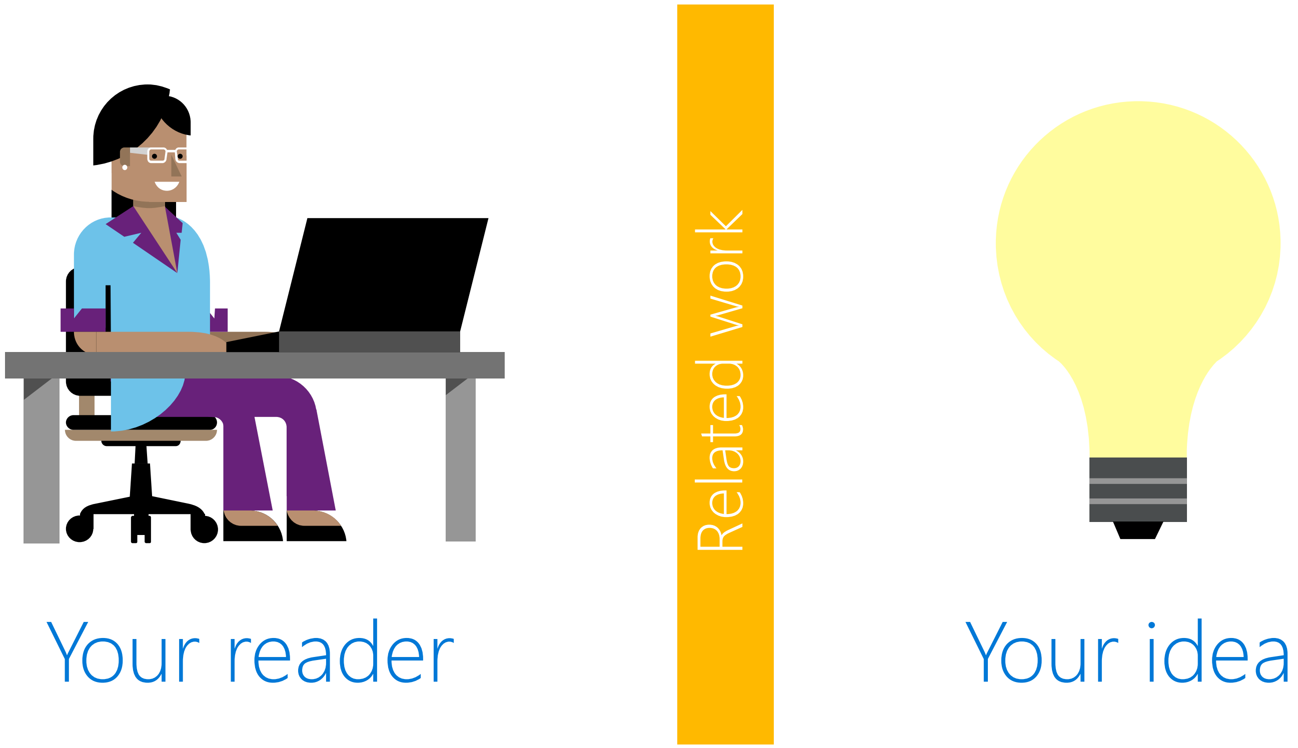
- Abstract (4 sentences)
- Introduction (1 page)
- Related work
- The problem (1 page)
- My idea (2 pages)
- The details (5 pages)
- Conclusions and further work (0.5 pages)

NO!

Structure

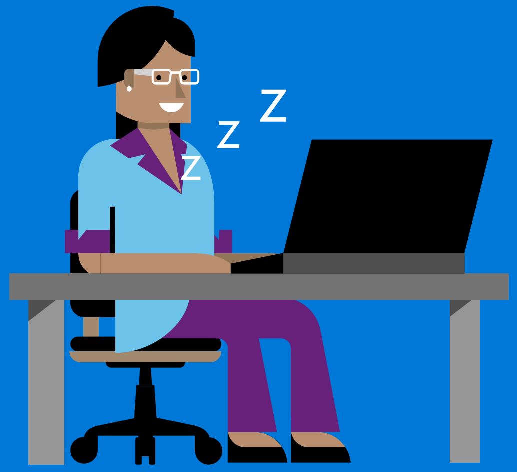
- Abstract (4 sentences)
- Introduction (1 page)
- The problem (1 page)
- My idea (2 pages)
- The details (5 pages)
- Related work (1-2 pages) ← YES!
- Conclusions and further work (0.5 pages)

No related work yet!



We adopt the notion of transaction from Brown [1], as modified for distributed systems by White [2], using the four-phase interpolation algorithm of Green [3]. Our work differs from White in our advanced revocation protocol, which deals with the case of priority inversion as described by Yellow [4].

No related work yet!



- Problem 1: the reader knows nothing about the problem yet; so your (highly compressed) description of various technical tradeoffs is absolutely incomprehensible
- Problem 2: describing alternative approaches gets between the reader and your idea

What if the problem is well known?

- Your idea could be derailed by a reader's preconception that the problem is
  - Solved
  - Impossible
  - Just like someone else's approach they know about
- Presenting related work after the introduction can mitigate these problems
- So refute these points with a forward reference the related work section
  - People expect you to compare to related work, so they will give you the benefit of the doubt

Added by mwh, 11/21/07

Writing Related Work: Give Credit

Fallacy

To make my work look good, I have to make other people's work look bad.

The truth: credit is not like money

- Warmly acknowledge people who have helped you
- Be generous to the competition.
  “In his inspiring paper [Foo98] Foogle shows.... We develop his foundation in the following ways...”
- Acknowledge weaknesses in your approach

Giving credit to others does not diminish the credit you get from your paper

Big picture: advancing knowledge

Added by mwh, 11/21/07

- Strive to be precise in your comparisons
- Best: use terminology you have used to explain your approach to explain related approaches. Crystallize the differences.
  - Helps readers, helps you
- Poor: focus on superficial differences between yours and related approaches
  - Inhibits knowledge of the true state of the art
- Discussion of related work should be a contribution in its own right

6. Put your readers first

Structure

- Abstract (4 sentences)
- Introduction (1 page)
- The problem (1 page)
- My idea (2 pages)
- The details (5 pages)
- Related work (1-2 pages)
- Conclusions and further work (0.5 pages)

Structure

3. The idea

Consider a bifircuated semi-lattice D, over a hyper-modulated signature S. Suppose pi is an element of D. Then we know for every such pi there is an epi-modulus j, such that $p_j < p_i$.

- Sounds impressive…but
- Sends readers to sleep, and/or makes them feel stupid

Presenting the idea

- Explain it as if you were speaking to someone using a whiteboard
- Conveying the intuition is primary, not secondary
- Once your reader has the intuition, she can follow the details (but not vice versa)
- Even if she skips the details, she still takes away something valuable

Conveying the intuition

Introduce the problem, and your idea, using EXAMPLES and only then present the general case

- Remember: explain it as if you were speaking to someone using a whiteboard

Using examples

The Simon PJ question: is there any typewriter font?

2 Background

To set the scene for this paper, we begin with a brief overview of the *Scrap your boilerplate* approach to generic programming. Suppose that we want to write a function that computes the size of an arbitrary data structure. The basic algorithm is "for each node, add the sizes of the children, and add 1 for the node itself". Here is the entire code for `gsize`:

```
gsize :: Data a => a -> Int
gsize t = 1 + sum (gmapQ gsize t)
```

The type for `gsize` says that it works over any type `a`, provided `a` is a *data* type — that is, that it is an instance of the class `Data`[1] The definition of `gsize` refers to the operation `gmapQ`, which is a method of the `Data` class:

```
class Typeable a => Data a where
  ...other methods of class Data...
  gmapQ :: (forall b. Data b => b -> r) -> a -> [r]
```

Example right away

The Running Example
[Stone]

- Understanding an example is an intellectual investment
  - Make your examples simple enough to understand but still convincing
  - Aim for reuse
- Ideal
  - First concept
  - Example of first concept
  - Next concept
  - Example embellished
  - Next concept followed by more embellishment …

Added by mwh, 11/21/07

Non-ideal approaches to examples

- First concept
- Next concept
- Next concept
- Example of first concept
- Example embellished
- More embellishment

Leaves reader unsure between concepts

- First concept
- Example of concept
- Next concept
- Different example
- Next concept
- Yet another example

Extra effort to understand each example

Added by mwh, 11/21/07

The details: evidence

- Your introduction makes claims
- The body of the paper provides evidence to support them
- Check each claim in the introduction, identify the evidence, and forward-reference it from the claim
- Evidence can be: analysis and comparison, theorems, measurements, case studies

Added by mwh, 11/21/07

General idea: Claim then Evidence

- The claim/evidence structure should occur throughout the paper
  - Top-down, as opposed to bottom-up, organization
- Each section should begin with a claim and/or summary
  - "This section proves that the boobaz approach is sound. To do this …"
  - "This section shows that boobaz performs well under a typical workload. We gathered …"
  - "Boobaz is distinct from other approaches to X primarily in that …"
- Same with subsections, even paragraphs

Added by mwh, 11/21/07

Wrong: Facts then Conclusions

- Temptation: present facts, then assess them
  - Like a mystery story: learn the facts of the crime, and then discover who did it!
- The problem: you don't want the reader to guess, you want to tell them what's important! Readers get frustrated without direction
- Strive to create "mental boxes" by foreshadowing your argument. Will fill in these boxes as you go [Harold Stone]

Added by mwh, 11/21/07

Putting the reader first

- Do not recapitulate your personal journey of discovery. This route may be soaked with your blood, but that is not interesting to the reader.

- Instead, choose the most direct route to the idea.

7. Listen to your readers

Getting help

- Experts are good
- Non-experts are also very good
- Each reader can only read your paper for the first time once! So use them carefully
- If you are a reader, be substantive ("I got lost here" is much more important than "Jarva is mis-spelt".)

Get your paper read by as many friendly guinea pigs as possible

Getting expert help

- A good plan: when you think you are done, send the draft to the competition saying "could you help me ensure that I describe your work fairly?".
- Often they will respond with helpful critique (they are interested in the area)
- They are likely to be your referees anyway, so getting their comments or criticism up front is Jolly Good.

Listening to your reviewers

Treat every review like gold dust

Be (truly) grateful for criticism as well as praise

This is really, really, really hard

But it's really, really, really, really, really, really, really, really, really, really important

Listening to your reviewers

- Read every criticism as a positive suggestion for something you could explain more clearly
- DO NOT respond "you stupid person, I meant X".
- INSTEAD: fix the paper so that X is apparent even to the stupidest reader.
- Thank them warmly. They have given up their time for you.

Summary

1. Don't wait: write
2. Identify your key idea
3. Tell a story
4. Nail your contributions
5. Related work: later
6. Put your readers first (examples)
7. Listen to your readers

More: www.microsoft.com/research/people/simonpj

Language and Style

Visual structure

- Give strong visual structure to your paper using
  - sections and sub-sections
  - bullets
  - italics
  - laid-out code
  - pictures and diagrams
- Your paper should "look" good
  - Fix orphans and widows
  - Keep text in the margins

Updated by mwh, 6/12/22

Visual structure

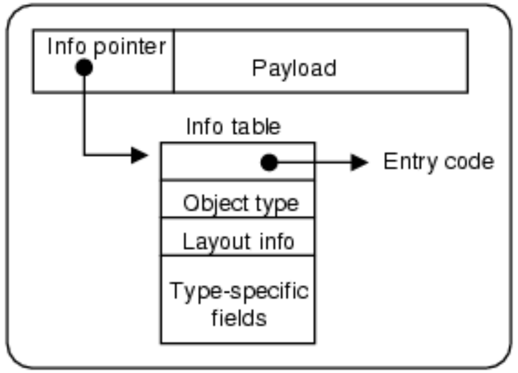


Figure 3. A heap object

The three cases above do not exhaust the possible forms of f. It might also be a *THUNK*, but we have already dealt with that case (rule THUNK). It might be a *CON*, in which case there cannot be any pending arguments on the stack, and rules UPDATE or RET apply.

4.3 The eval/apply model

The last block of Figure 2 shows how the eval/apply model deals with function application. The first three rules all deal with the case of a *FUN* applied to some arguments:

- If there are exactly the right number of arguments, we behave exactly like rule KNOWNCALL, by tail-calling the function. Rule EXACT is still necessary — and indeed has a direct counterpart in the implementation — because the function might not be statically known.
- If there are too many arguments, rule CALLK pushes a *call*

remainder of the object is called the *payload*, and may consist of a mixture of pointers and non-pointers. For example, the object $CON(C\ a_1 \ldots a_n)$ would be represented by an object whose info pointer represented the constructor C and whose payload is the arguments $a_1 \ldots a_n$.

The info table contains:

- Executable code for the object. For example, a *FUN* object has code for the function body.
- An object-type field, which distinguishes the various kinds of objects (*FUN*, *PAP*, *CON* etc) from each other.
- Layout information for garbage collection purposes, which describes the size and layout of the payload. By "layout" we mean which fields contain pointers and which contain non-pointers, information that is essential for accurate garbage collection.
- Type-specific information, which varies depending on the object type. For example, a *FUN* object contains its arity; a *CON* object contains its constructor tag, a small integer that distinguishes the different constructors of a data type; and so on.

In the case of a PAP, the size of the object is not fixed by its info table; instead, its size is stored in the object itself. The layout of its fields (e.g. which are pointers) is described by the (initial segment of) an argument-descriptor field in the info table of the FUN object which is always the first field of a PAP. The other kinds of heap object all have a size that is statically fixed by their info table.

A very common operation is to jump to the entry code for the object, so GHC uses a slightly-optimised version of the representation in Figure 3. GHC places the info table at the addresses *immediately*

Rule of 2

- If you add a subsection to a section, you should have at least a second one
  - Likewise with a paragraph in a subsection
- Otherwise, why bother subdividing?
  - When dropping a subsection heading, consider retitling the section

Added by mwh, 6/12/22

The Body of a Section [Stone]

- What happens here
- How this fits (optional)
- The results
- Transition

In this section …

This section continues the derivation by …

Thus far, the discussion has … Here, …

Added by mwh, 11/21/07

Use the active voice

The passive voice is "respectable" but it deadens your paper. Avoid it at all costs.

No!	Yes!
It can be seen that…	We can see that…
34 tests were run	We ran 34 tests
These properties were thought desirable	We wanted to retain these properties
It might be thought that this would be a type error	You might think this would be a type error

Use simple, direct language

No!	Yes!
The object under study was displaced horizontally	The ball moved sideways
On an annual basis	Yearly
Endeavour to ascertain	Find out
It could be considered that the speed of storage reclamation left something to be desired	The garbage collector was really slow

Twice told, different ways [Stone]

- Clarify tricky concepts by describing them twice
  - Picture with text
  - Text with equation
  - Methodology with example

$$f(x) = \Sigma_i\, w(i) \times B(i)$$

That is, f(x) is a weighted sum of Bs.

Added by mwh, 11/21/07

References

- References are annotations, not nouns
  - Sentence should still make sense if you remove the references
- *Castelli and Brown [3] showed that …*
  - Not *[3] showed that …*
- *Some prior systems are unsound [3,4].*
  - Not *The systems presented in [3,4] are unsound.*
- `acmart.cls` *provides* `\citet{}`
  - When you want to use a reference as a noun

Added by mwh, 11/21/07

A Findable Title

- The first thing readers will see of your paper is its title
  - Should motivate them to read the abstract
- How will readers find your paper in the first place?
  - Internet search – title should have the right keywords!
  - Paper-watch service (arXiv, Google Scholar, ...) – topic should be evident from title (and metadata)

Added by mwh, 6/12/22