Success as a Student Researcher: A Discussion of Best Practices

Fall 2018 – Part 1

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Why do we do this seminar?

Doing good research is hard

- There are many new skills to learn
  - Understanding the literature
  - Setting up your experiments/simulations
  - Data analysis
  - Interpretation of your results
  - Writing and presenting
- There is often a long time-scale on rewards
- At many levels, you are responsible for directing your own education

Your strategic plan

- A strategic plan has three parts:
  - Where are you today? Graduate school should be part of your strategic plan
  - Where do you want to be in the future (5, 10, 20 years from now)
  - How do you get from here to there?

A strategic plan is a roadmap for your (professional) life

What is research?

What IS research?

- The process of finding out something that we (everyone) do not already know
- Builds upon the extant knowledge base
- It is **methodical**, repeatable and verifiable
  - You can specify, in advance, a procedure to accomplish your stated objective

Why is problem choice so important?

- You will be spending a lot of time on your problem
- Personal interest will keep you motivated
- "When one can achieve self-expression in science, work becomes revitalizing, and laden with personal meaning." (Alon)

Finding an advisor

- Ideally, you have selected your school by identifying faculty you would like to work with
  - If not, start looking NOW

- A good advisor will serve as a mentor **AND** a source of technical assistance
  - They should help you set and achieve short-term and long-term goals

A research topic must …

- be research
- not have been done before
- be significant
- have a greater than zero probability that you can do it
- lend itself to a viable research plan
- be accomplished with the facilities you have available
- fit into your strategic plan

Factors to consider

- Feasibility: How hard or easy it is
  - Problems are always more difficult than they look

- Importance: Impact on the community and beyond
  - Who cares?
  - What will they do when they see your work?
  - How long will the answer be important?

Factors to consider

- Interest
  - Both internal and external
  - Do you have a passion for the topic?
  - What will keep you working on it?

- Competence
  - Why are you qualified?
  - Do you have an advantage?

Establishing a research objective / direction

Heilmeier questions

- What are you trying to do?
- How is it done today? What are the limitations of current practices?
- What is new in your approach and why do you think it will succeed?
- Assuming success, what differences does this make to us and society?

Heilmeier questions

- What are the risks, and what can we do about them?
- How long will it take?
- How much will it cost?
- What is the timeline and what are the deliverables that we should expect throughout the project?

Establishing a research objective

- Concise statement of what you intend to find out that we don't already know

- Do not use words that mean "not research" to define your objective
  - Develop
  - Design
  - Optimize
  - Control
  - Manage

How to do it right!

- The research objective of this project is to account for uncertainty in engineering design decision making through the application of utility theory

- The research objective of this project is to measure the cross-section of the muon-neutrino interaction at 5 GeV accurate to 10%

Responsible research conduct

Research responsibility

- Your obligation:
  - Clear records
  - Honest results
  - Appropriate acknowledgment
    - authorship, citations, acknowledgments, funding

- Responsibility to:
  - Your advisor and group
  - The university
  - The sponsor
  - The law
  - The scientific community
  - The public-at-large

Considerations related to research and scholarly integrity

- Personal honesty, ethics, and morals
- Expertise in the field of study – doing good science
- Professional codes of conduct and research practice, including publication policies established by professional journals
- Data ownership and control
- Institutional policies and regulations
- Governmental policies and regulations

Do the right thing!

Responsible Conduct of Research, Scholarship, and Creative Activities
Michigan State University Graduate School, 2010 http://grad.msu.edu/

Considerations related to research and scholarly integrity

Continuum	Definition
Research integrity	Best practices
Questionable research practices	Sloppy work, lack of expertise, or ignorance of policies and regulations (other possibilities exist!)
Unacceptable research practices	Failure to correctly observe applicable policies and regulations
Research misconduct	Deliberate efforts to plagiarize, fabricate, or falsify research data

Responsible Conduct of Research, Scholarship, and Creative Activities
Michigan State University Graduate School, 2010 http://grad.msu.edu/

Research misconduct

- Misconduct that distorts scientific knowledge
  - Fabrication – reporting of non-existent data
  - Falsification – selective reporting of data, misrepresentation

- Misconduct that misleads the scientific community
  - Plagiarism
  - Inappropriate authorship
  - Duplicate publication
  - Abuse of peer-review

Research misconduct

- Misconduct relating to human subjects
  - Consent issues
  - Exploitation issues (e.g. financial, power…)
- Other
  - Conflict of interest
  - Poor record-keeping
  - IRB and IACUC approval issues
- HONEST, unintentional error is not misconduct. But BE CAREFUL.

Serious deviation: possible scenarios

- Violation of confidentiality in proposing, performing, reviewing, or reporting research
- Misrepresenting credentials in proposing or presenting research
- Stealing, destroying, or damaging the research property of others with intent to alter the research record
- Serious or continuing noncompliance with federal regulations or University policies

Nature 453, 980-982 (19 June 2008)

- SURVEY of 2,212 Researchers
  - Observed 201 instances of misconduct
  - E.G.
    - *"A post doc changed the numbers in assays in order to 'improve' the data."*
    - *"A colleague duplicated results between three different papers but differently labeled data in each paper."*
    - *"A co-investigator on a large, interdisciplinary grant application reported that a postdoctoral fellow in his laboratory falsified data submitted as preliminary data in the grant. As principal investigator of the grant, I submitted supplementary data to correct the application."*
    - *"A colleague used Photoshop to eliminate background bands on a western blot to make the data look more specific than they were."*

Tuskegee Syphilis Study (1932-27)

- Poor African-Americans with advanced syphilis recruited to trial to study their "bad blood"

- Deliberately untreated to follow natural history of syphilis infection, even after penicillin available

- Over 400 men and their families involved
- Breach of Human Rights
- Lead to Belmont Report and protection of Human Subjects laws

Why does this happen?

- Sloppiness when conducting the literature review (e.g., cut & paste & forget the original citation)
- Inadequate knowledge of research literature
- Inadequate expertise in research methods
- Pressure from others to produce data quickly
- Time crunch
- Malfunctioning equipment
- Poor mentoring
- Personal problems
- Cultural differences

Consequences

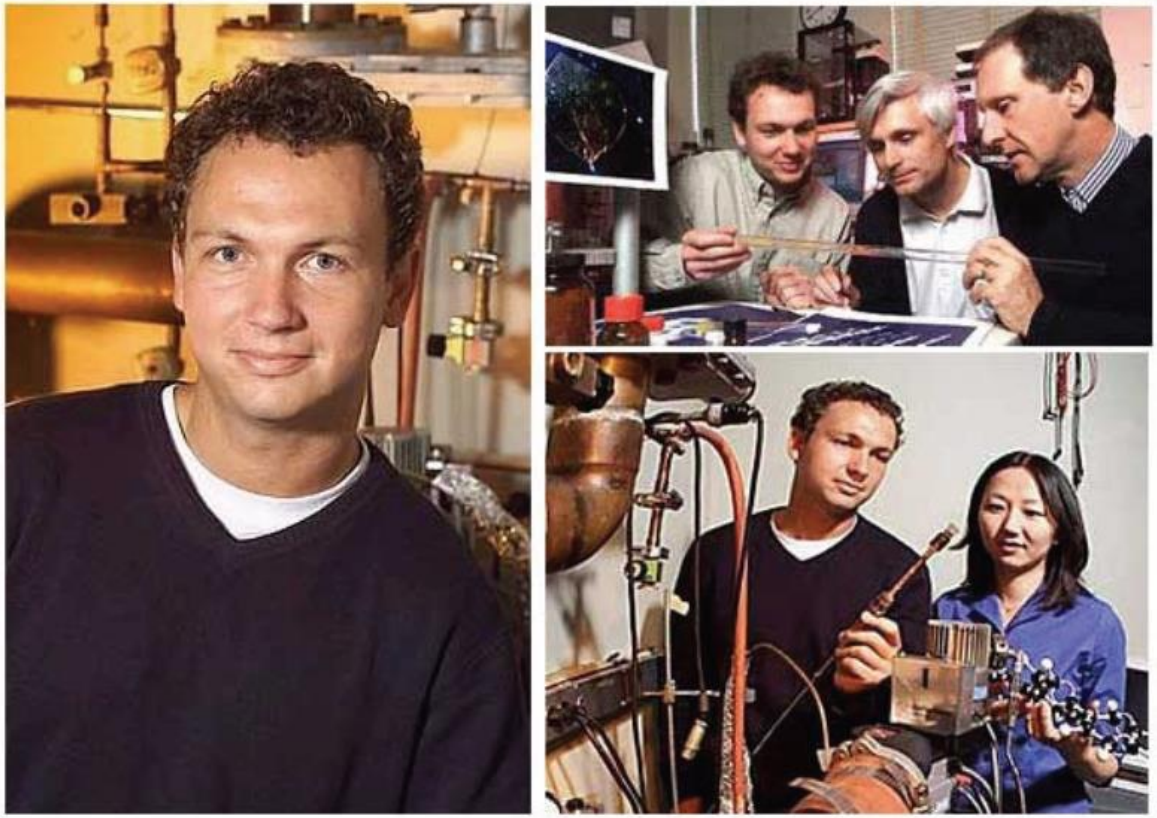
- Investigation at institutional to federal level
- Withdrawal or correction of all pending and published papers and abstracts affected by the misconduct
- Reprimand, removal from project, rank and salary reduction, dismissal
- Restitution of funds to the granting agency
- Ineligibility to apply for Federal grants for years (debarment)
- Criminal prosecution
- **I.E. the end of your research career!**

Who is accountable

- Investigated
  - All authors that are involved in the specific data in question

- Held accountable
  - Primary author
  - Other authors whose results are found culpable
  - The PI

Real example: Jan Hendrik Schon



Jan Hendrik Schon

4 years after his Ph.D. (1997→2001), Schon was listed as an author on a new paper every 8 days.

but others couldn't reproduce his results, and then found suspicious things in Schon's papers, like 2 curves with the same noise

Real example: Jan Hendrik Schon

SCIENTIFIC MISCONDUCT

Bell Labs Fires Star Physicist Found Guilty of Forging Data

Like the mythical Icarus, whose waxen wings melted when he flew too close to the sun, the soaring career of Jan Hendrik Schön came crashing down to Earth last week. Schön, a 32-year-old physicist at Bell Laboratories in Murray Hill, New Jersey, faked experimental results in at least 17 published papers, according to a report released 25 September by a panel of independent investigators. Schön had been fired from Bell Labs the previous evening, after officials there received the report. The findings mark this as one of the most extensive cases of scientific misconduct in modern history and signal a low-water mark for Bell Labs, an institution already reeling from economic troubles of its parent company, Lucent Technologies.

"It's a big train wreck and very sad," says Lydia Sohn, a Princeton University physicist who was one of the first to point out Schön's apparent manipulation of data. "But this shows that the system of checks and balances in science works." Others were less consoled. "If this guy [had been] a little less blatant, he could have succeeded. That's the terrifying thing," says Paul McEuen, a physicist at Cornell University in Ithaca, New York.

The panel cleared Schön's co-authors of any direct scientific misconduct. But it left open questions that are likely to reverberate through scientific circles for years to come. Chief among them are whether papers Schön co-authored that were not reviewed by the committee are valid and whether Schön's co-authors, the journals that published his papers, or scientific referees should have caught the fraud earlier. "There are other questions, and they are for others to address," says Stanford University physicist Malcolm Beasley, who chaired the panel.

Bell Labs hired Schön as a postdoctoral researcher in 1998 to work with Bertram Batlogg—then Bell's head of solid state physics research—on investigating how electrical charges move through crystals of organic semiconductors. Working with crystal grower Christian Kloc, Schön and Batlogg made rapid progress. Early on, they reported a new way to inject large electric currents into their organic crystals. That advance produced an extraordinary string of effects, including superconductivity, the fractional quantum Hall effect, and laserlike behavior. "He rediscovered everything in condensed matter physics in the last 60 years" in organic materials, Sohn says.

In his 4-year career at Bell Labs, Schön's steady stream of stunning breakthroughs promised to revolutionize the fields of organic electronics, superconductivity, and nanotechnology. By the beginning of this year he had produced a string of more than 90 papers, most of which listed him as the lead author. In 2001, Schön churned out a new paper on average every 8 days, a level of productivity nearly unheard of in physics.

Image not available for online use.

Shattered trust. Panel fingered Schön (left) for misconduct but cleared former partners Kloc and Batlogg.

To researchers watching from the wings, Schön seemed to be a Tiger Woods of physics, a young prodigy overwhelming the competition. "These papers came out and you'd say, 'Oh, no,' " recalls Arthur Ramirez, a physicist at Los Alamos National Laboratory in New Mexico. "It would be a monthly demonstration of how stupid you are. He was creating a new field every 2 months."

Late last year, two of Schön's breakthroughs rocked the nascent community of nanotechnologists. In the 18 October 2001 issue of *Nature*, Schön, working with Bell Labs colleagues Zhenan Bao and Hong Meng, reported a novel transistor in which a single layer of molecules carried out the critical role of switching between two electronic states, the foundation of more-complex computer technology. In the 7 December 2001 issue of *Science* they went further, reporting evidence of a single molecule acting as a switch.

The sensational results were hailed as a triumph of nanotechnology and a key step toward the ultimate in miniaturization of computer technology. In April, Schön received the Outstanding Young Investigator award and $3000 in prize money from the Materials Research Society. *Technology Review* magazine named him one of science's top young innovators in its June issue, which went to the printers before the allegations of misconduct surfaced in May. Around the same time, Schön was also being considered for the directorship of the Max Planck Institute for Solid State Research in Stuttgart, Germany.

But Schön's bold results turned out to be his undoing, attracting intense scrutiny to his work. In April, outside researchers noticed that a figure in the *Nature* paper on the molecular-layer switch also appeared in a paper *Science* had just published on a different device. Schön promptly sent in a corrected figure for the *Science* paper. But the incident disturbed McEuen, who says he was already suspicious of results reported in the two papers. On 9 May, McEuen compared figures in some of Schön's other papers and quickly found other apparent duplications. The next day, he alerted officials at Bell Labs, who immediately organized a five-member panel to review the allegations and a host of others that poured in shortly after (*Science*, 24 May, p. 1376; 31 May, p. 1584; 5 July, p. 34).

The panel ultimately focused on 24 allegations of misconduct in 25 separate papers that included 20 co-authors. In its inquiry, the panel sent each co-author a list of questions detailing concerns raised about studies in which they participated. In late July, panel members visited Bell Labs and conducted extensive interviews with Schön and his three primary co-authors, Batlogg, Kloc, and Bao. They also reviewed computer logs and data files. After sifting through all the evidence, they concluded that Schön had either falsified or fabricated data in 16 of the 24 cases. He had also deleted his original data files, making it impossible to check his

PAPERS IN WHICH MISCONDUCT WAS FOUND

"Ambipolar pentacene ...," *Science* (11 February 2000)

"A superconducting field-effect switch," *Science* (28 April 2000)

"An organic solid state injection laser," *Science* (28 July 2000)

"A light-emitting field-effect transistor," *Science* (3 November 2000)

"Superconductivity at 52 K in ... C_{60}," *Nature* (30 November 2000)

"Perylene: A promising ...," *Appl. Phys. Lett.* (4 December 2000)

"Ambipolar organic devices ...," *Synthetic Metals* (2001)

"Gate-induced superconductivity ...," *Nature* (8 March 2001)

"Solution processed CdS ...," *Thin Solid Films* (2 April 2001)

"High-temperature superconductivity in lattice-expanded C_{60}," *Science* (28 September 2001)

"Ballistic hole transport in pentacene with a mean free path exceeding 30 μm," *J. Appl. Phys.* (1 October 2001)

"Self-assembled monolayer organic ...," *Nature* (18 October 2001)

"Superconductivity in $CaCuO_2$ ...," *Nature* (22 November 2001)

"Field-effect modulation ...," *Science* (7 December 2001)

"Fast organic electronic circuits based on ambipolar pentacene ...," *Appl. Phys. Lett.* (10 December 2001)

"Nanoscale organic transistors ...," *Appl. Phys. Lett.* (4 February 2002)

"Sputtering of alumina thin films for field-effect doping," preprint

Real example: Jan Hendrik Schon

Duplicate Publication: for real!

- Two papers published in top-level journals, within one year
- Significant duplication of figures (data) and results
- Same authors, different order, different corresponding author
- Paper #1 was published before paper #2 was submitted
- Paper #2 does not cite paper #1

Paper #1

For the CNT-reinforced sandwich beam, the analysis shows good correlation with test data for a damping ratio (Z_b) of 0.3 and a cross-sectional stiffness (EI) of 87.7×10^{-3} N m^2. Therefore, we conclude that carbon nanotube reinforcement results in a 200 % increase in the baseline structural damping (due to the frictional energy dissipation during the movement of individual nanotubes in the film) and a 30 % increase in the baseline bending stiffness (due to stiffening of the 2 mm adhesive sub-layer). Based on the observed increase in cross-sectional stiffness of the laminate from 65.1×10^{-3} N m^2 to 87.7×10^{-3} N m^2, the modulus of the carbon nanotube film was estimated using the Bernoulli–Euler theory as 41.2×10^6 psi (284 GPa). Table 2 compares the properties and operating conditions of the carbon nanotube film with commercially available viscoelastic damping polymers such as 3M1SD-112[20] and Soundcoat Dyad-606.[21]

Paper #1

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What is a difficult situation?

- Conflicts with your mentor about expectations for degree completion or research assignments
- Conflicts about issues such as authorship, data management, lab safety, protection of human subjects, animal welfare, or conflict of interest
- Problems with communication or collegiality in the research environment

What is suspected misconduct?

- Fabrication of data
- Falsification
- Plagiarism
- Or a serious deviation from commonly accepted practices in your discipline

If you face a difficult situation

- Make notes about your observations
  - Focus on what you know or have observed
  - Do not rely upon hearsay
  - Avoid emotional reactions

- Get the big picture
  - Discuss the matter with the people involved in the situation – understand different perspectives
  - Ask for clarification, e.g., "I don't understand this" or "what is the right thing to do in this situation" or "what did you mean by"
  - Do not make the situation worse – avoid rumors

If you face a difficult situation

- Do not take unilateral action – talk to someone such as your mentor, advisor, or lab director
  - Ask for advice about resolving the problem
  - Seek education about applicable procedures, policies, and rules
  - Be a responsible adult – if you are part of the problem, admit to your mistakes and ask for advice about how to help rectify the situation

- If the matter is not resolved amicably, seek advice from the NCSU Research Integrity Officer

NCSU resources

- http://research.ncsu.edu/sparcs/training/training-rcr-courses/
- Preparing Future Leaders Blog: http://pfl.grad.ncsu.edu/category/blog/
- Research integrity officer:

  Richard Best

  919-515-0158

  richard_best@ncsu.edu

Confidentiality

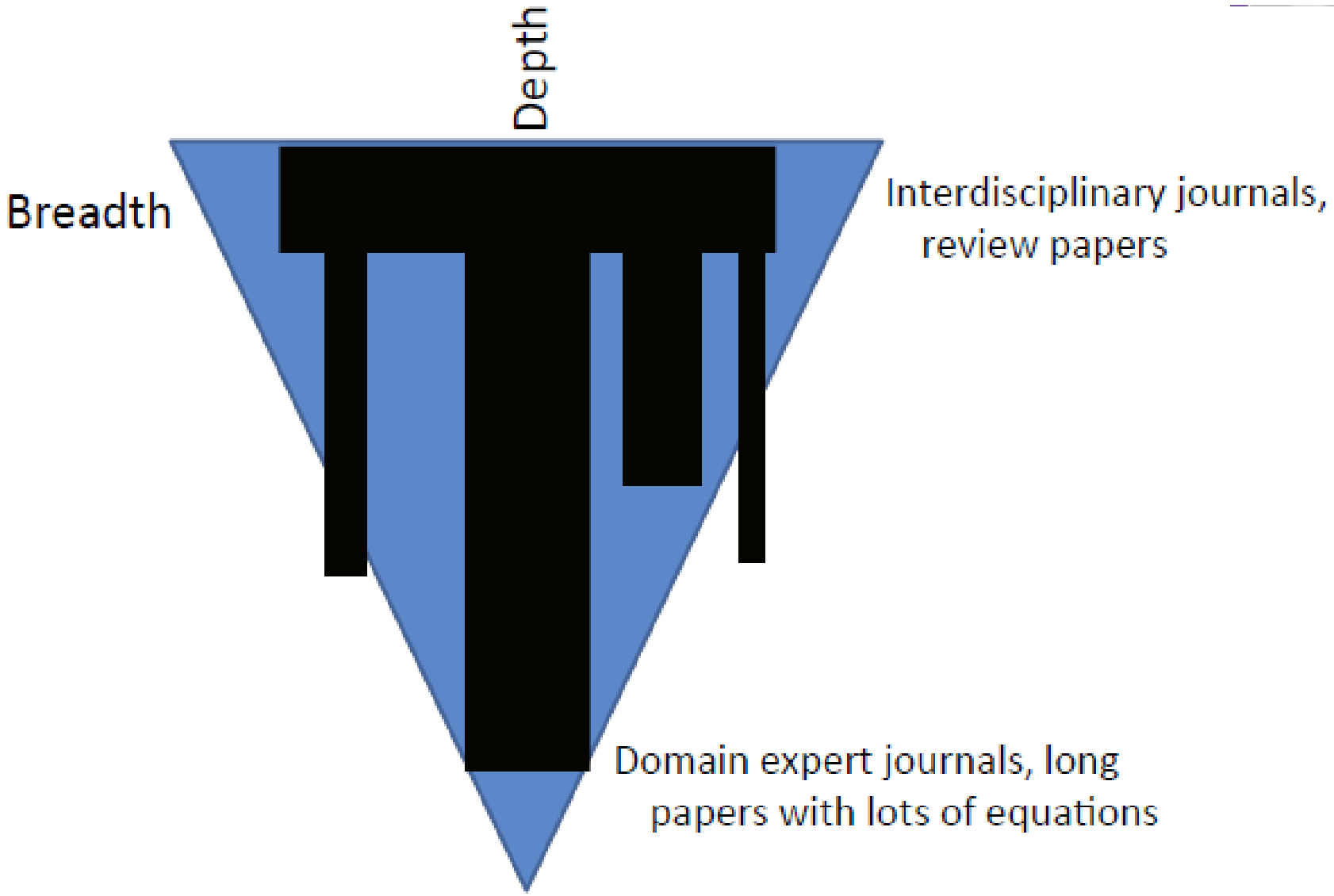
- Be aware of restrictions for your specific research project

- Proprietary information
- Personal health records
- Unpublished research

Understanding the work presented in the literature

How do I…

- …know what and where to search?
- …do the search?
- …know if what I'm reading is important?
- …keep track of what I read?
- …keep up to date on the latest "news" after my preliminary search?
- …maintain my own records?


Depth
Breadth
Interdisciplinary journals, review papers
Domain expert journals, long papers with lots of equations

Searching a new topic

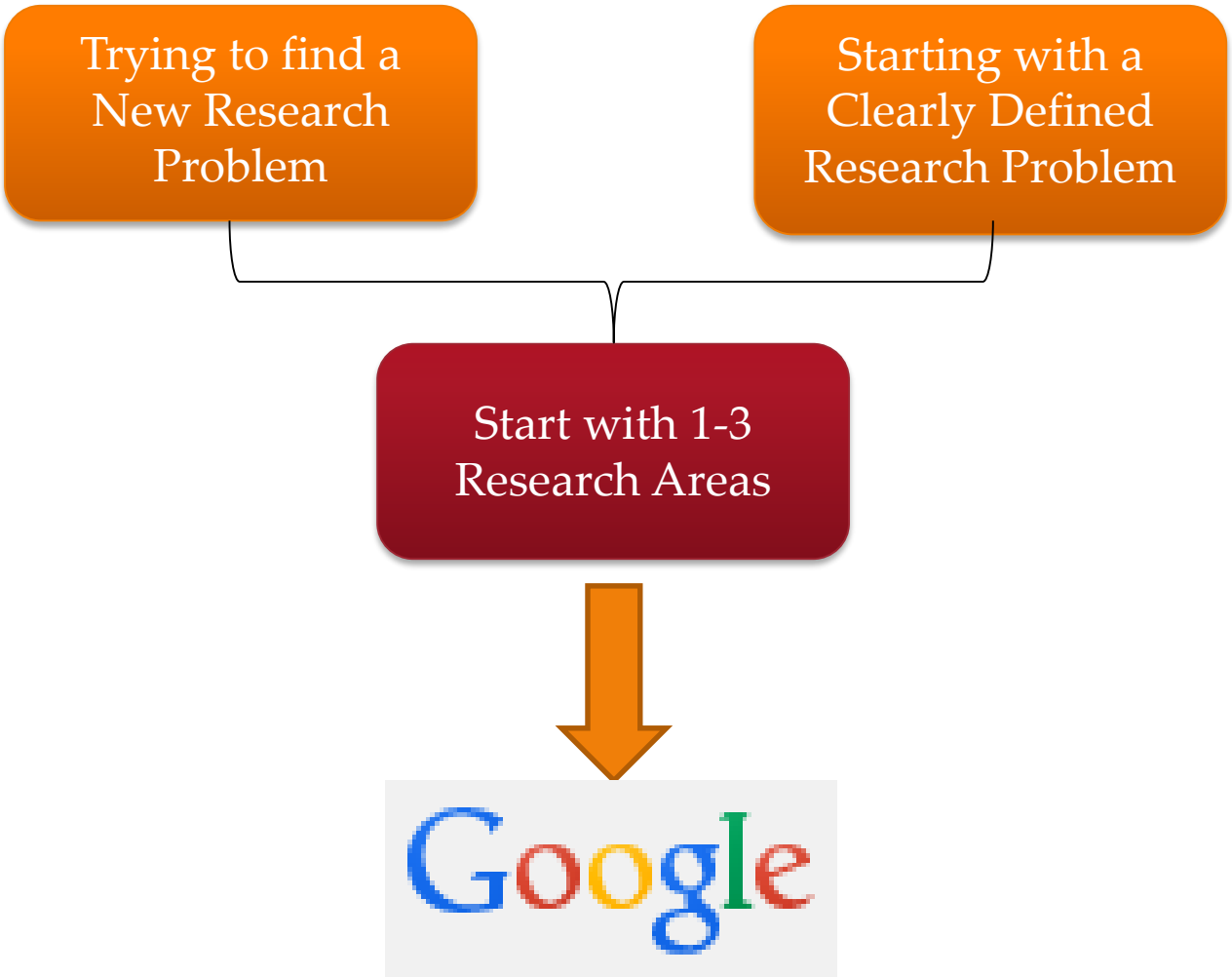
- Identify **keywords** for your topic and browse ALL the articles you find
- Identify key **sources** and browse them
- Identify key **people** (leaders! heroes!) and look up their work
- Identify **review papers**

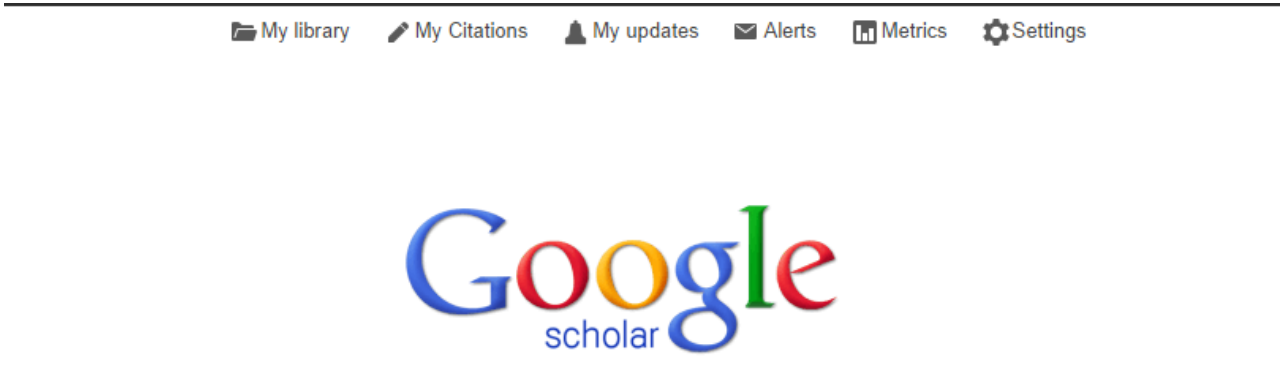
- Follow the **references**
- Revise the **keywords**
- Create **alerts**

What sources should you read?

- Journals
  - Inside your field
  - Interdisciplinary (e.g. Nature, Science)
  - Outside your field but encompassing complementary topics
- Conference proceedings (abstracts or papers)
  - Newest research
  - Check out webpages for specific conferences
- Theses/Dissertations
  - More detail than papers
- Patents and industry reports
  - If your work has commercial applications, patents can give design/process details.
  - Can understand state of intellectual property

Conducting a literature review

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H Soo Im, KE Alter, S Brochard, C Pons, FT Sheehan - Journal of Biomechanics, 2014
EMG Driven muscle Force Estimator (EMG-FE) Version 1.0 r7 distribution 1 User Guide
LL Menegaldo, LF de Oliveira - 2014
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Stand on the shoulders of giants

Google Scholar Results

An overview of evolutionary algorithms in multiobjective optimization [PDF] from whiterose.ac.uk
CM Fonseca, PJ Fleming - Evolutionary computation, 1995 - MIT Press
... (2013) Evolutionary **multiobjective optimization** in water ... (2013) BSTBGA: A hybrid genetic algorithm for constrained **multi-objective optimization** problems. ... (2012) Optimal **design** of actively controlled adjacent structures for balancing the mutually conflicting **objectives** in **design** ...
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A Messac - AIAA journal, 1996 - arc.aiaa.org
... (2012) Condition based maintenance **optimization** considering multiple **objectives**. ... Visualization (HRV) method with range-based preferences for **multi-objective** decision making. ... (2010) Integration of Preferences in Hypervolume-Based **Multiobjective** Evolutionary Algorithms by ...
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RT Marler, JS Arora - Structural and multidisciplinary **optimization**, 2004 - Springer
... A closer look at drawbacks of minimizing weighted sums of **objectives** for Pareto ... Kluwer Academic Publishers; Murata, T.; Ishibuchi, H.; Tanaka, H. 1996: **Multi-objective** genetic algorithm ... 30, 957–968; Narayana, S.; Azarm, S. 1999: On improving **multiobjective** genetic algorithms ...
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A multi-objective optimization for green supply chain network design
F Wang, X Lai, N Shi - Decision Support Systems, 2011 - Elsevier
... However, any "**design**" in nature is usually involving trade-offs among different incompatible **objectives**. ... The **multi-objective** model explicitly considers the environmental issues by introducing a new category of decision variables: the ... d i p the demand of customer for **product**. s i p ...
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Multiobjective evolutionary algorithms: Analyzing the state-of-the-art
DA Van Veldhuizen, GB Lamont - Evolutionary computation, 2000 - MIT Press
Abstract Solving optimization problems with multiple (often conflicting) objectives is, generally, a very difficult goal. Evolutionary algorithms (EAs) were initially extended and applied during the mid-eighties in an attempt to stochastically solve problems of this ...
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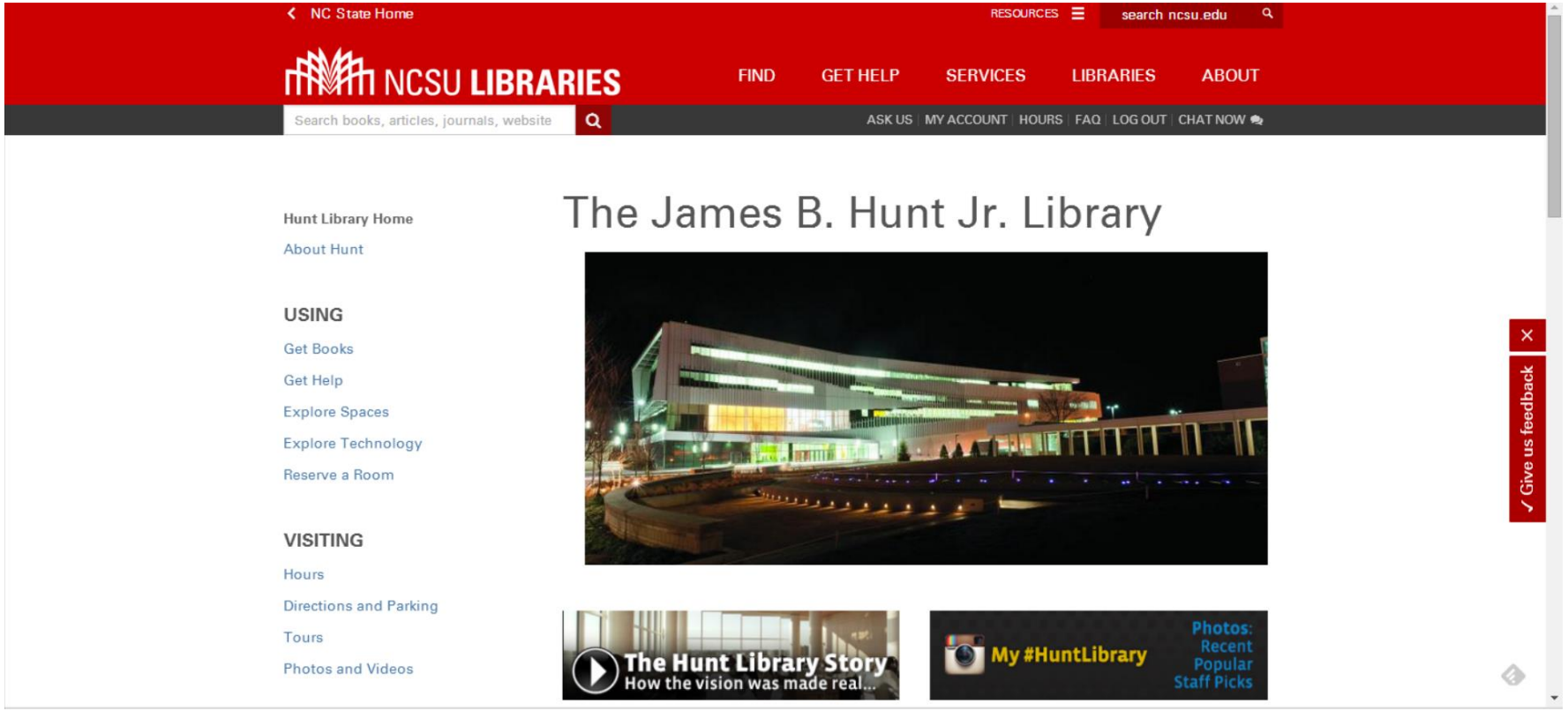
DA Van Veldhuizen, GB Lamont - Evolutionary Computation - Citeseer
Abstract Solving optimization problems with multiple (often conflicting) objectives is, generally, a very difficult goal. Evolutionary algorithms (EAs) were initially extended and applied during the mid-eighties in an attempt to stochastically solve problems of this ...
Cite

Multiobjective Evolutionary Algorithms: Analyzing the State-of-the-Art
DA Van Veldhuizen, GB Lamont - 2000 - citeseer.ist.psu.edu
Abstract: Solving optimization problems with multiple (often conflicting) objectives is, generally, a very difficult goal. Evolutionary algorithms (EAs) were initially extended and applied during the mid-eighties in an attempt to stochastically solve problems of this ...
Cite

Multiobjective evolutionary algorithms: analyzing the state-of-the-art.
DA Van Veldhuizen, GB Lamont - Evolutionary computation, 1999 - europepmc.org
Solving optimization problems with multiple (often conflicting) objectives is, generally, a very difficult goal. Evolutionary algorithms (EAs) were initially extended and applied during the mid-eighties in an attempt to stochastically solve problems of this generic class. During the ...

…or, Google the author

The library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Photos and Videos
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The Hunt Library Story
How the vision was made real...
My #HuntLibrary
Photos:
Recent
Popular
Staff Picks
Give us feedback

Down the rabbit hole

- Pull the cited papers
- **READ** the cited paper itself before citing it – don't rely on another paper's interpretation. Sometimes they aren't right! Don't propagate error!
- Look at the citation numbers of papers to gauge importance (date of publication and subfield will influence this, so this is imperfect)
  - Science Citation Index, Web of Science, Sci Search

Understand your community

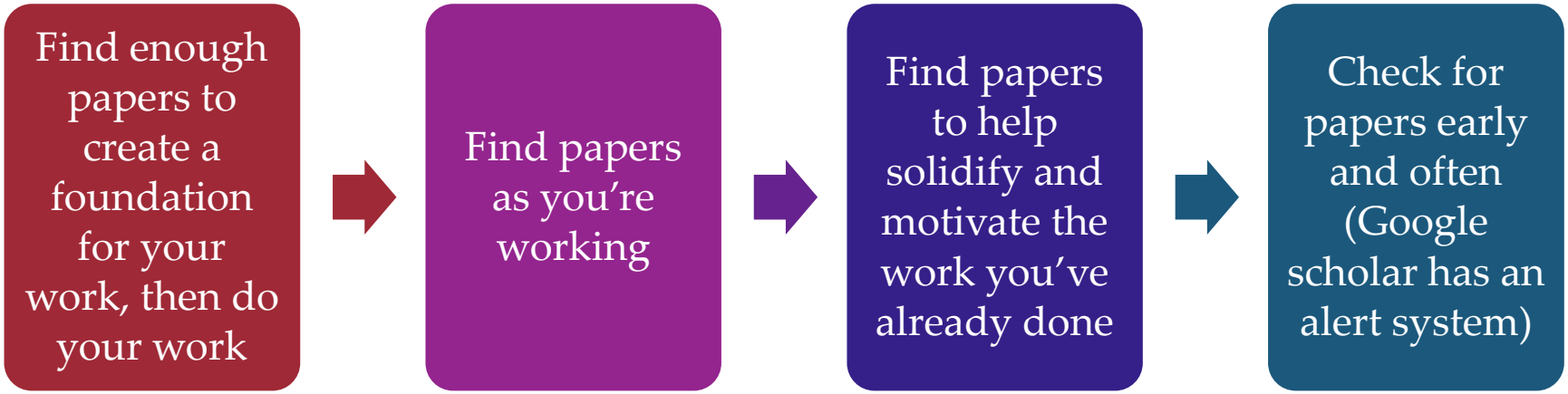
- Identify the research groups that are most relevant
  - Follow their work
  - Suggest as reviewers
  - Make contact at meetings
- Flag important methods
  - Understand best practices
  - Identify different information obtained from different approaches
  - Incorporate into your work
- Keep track of next steps suggested in discussions or raised in your reading
- Identify ways in which your work builds on other groups

Research social networks

- LinkedIn
- ResearchGate
- ResearcherID
- ORCID
- GoogleScholar

- Unique identifier to link you to research, distinguish you from other researchers
- Provides citation information
- Links to co-authors

The process is iterative



Reading papers

Questions to ask while you are reading…

- Who are these authors? Do they have the relevant expertise?
- Is the source credible?
- Do I understand the terminology that is being used in the paper?

Start with the abstract

Exploring the Effectiveness of Using Graveyard Data When Generating Design Alternatives

The objective of this paper is to demonstrate that unique alternative designs can be efficiently found by searching the discarded data (or graveyard) from a multiobjective genetic algorithm (MOGA). Motivation for using graveyard data to generate design alternatives arises from the computational cost associated with real-time design space exploration of multiobjective optimization problems. The effectiveness of this approach is explored by comparing (1) the uniqueness of alternatives found using graveyard data and those generated using an optimization-based search, and (2) how alternative generation near the Pareto frontier is impacted. Two multiobjective case study problems are introduced—a two bar truss and an I-beam design optimization. Results from these studies indicate that using graveyard data allows for the discovery of alternative designs that are at least 70% as unique as alternatives found using an optimization-based alternative identification approach, while saving a significant number of functional evaluations. Additionally, graveyard data are shown to be better suited for alternative generation near the Pareto frontier than standard sampling techniques. Finally, areas of future work are also discussed. [DOI: 10.1115/1.4024913]

Keywords: design alternatives, multiobjective optimization, multiobjective genetic algorithms, design space exploration, MGA

Start with the abstract

Purpose (why)

Exploring the Effectiveness of Using Graveyard Data When Generating Design Alternatives

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Keywords: design alternatives, multiobjective optimization, multiobjective genetic algorithms, design space exploration, MGA

Start with the abstract

Purpose (why)

Methodology (how)

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Methodology (how)

Results (what was found)

Conclusions (what it means)

One strategy…

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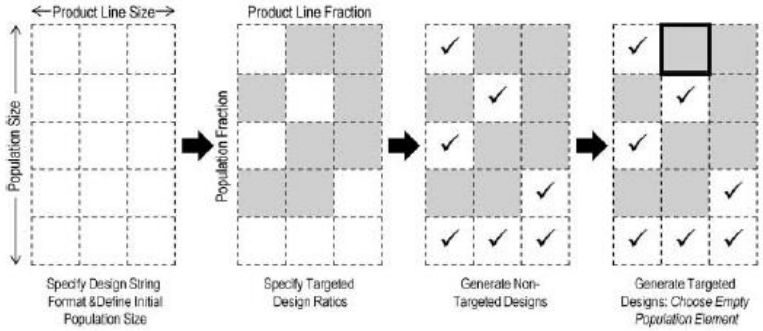
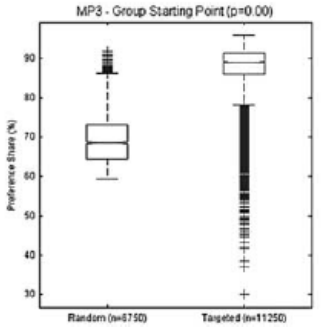
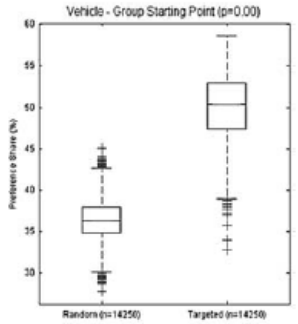
1. Introduction

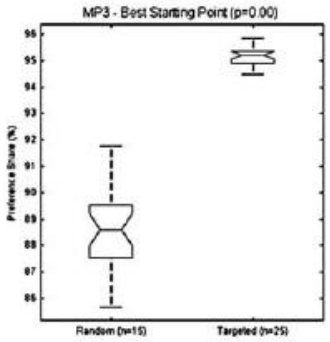
Product designers face the challenge of creating products in markets where customers have highly heterogeneous preferences. Improving performance in market-related objectives, such as market share of preference, requires a product line, *i.e.* a set of related products that are offered by a single company. This is different from a product family where commonality of features, components and subsystems is often explicitly enforced (Simpson, Maier, and Mistree 2001).

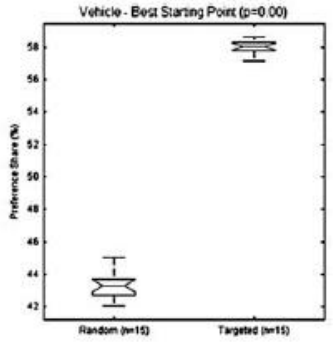
Customers also desire products that maximize their value for money (Prahalad and Mashelkar 2010). This leads to complex design problems that require: (1) advanced techniques to capture and model customer preferences for product features; and (2) optimization techniques capable of searching the expansive mixed-integer design space associated with the resulting combinatorial problem. The nature of many feature-packaging problems supports the use of heuristic optimiza-











Why the introduction is important

- Tells you what is known in the field
- Explains the limitations of our current understanding
- Leads to a focal point – what question is going to be answered

PROVIDES PERSPECTIVE

Questions to ask while you are reading…

- Is there other work I should be looking at first (previous papers in this area)
- Who can I talk to about the confusing parts of this paper?
- Am I spending too much time reading the less important parts?

Three pass approach

- Pass 1: General idea
- Pass 2: Content, but not details
- Pass 3: Understand in depth

Pass 1

- READ:
  - Title, abstract, introduction
  - Section and subsection headings (if they exist)
  - Glance at math
  - Conclusions
  - Skim references
- ANSWER:
  - Category: What kind of paper is this? Clinical? Technical development?
  - Context: What is it related to?
  - Correctness: Assumptions valid?
  - Contributions: Main contributions.
  - Clarity: Well-written?
- Keep going? Peripheral to research area?

Pass 2

- READ:
  - Careful look at figures/graphs
  - Mark relevant references you haven't read
- ANSWER:
  - Summarize main thrust with evidence – cover sheet/notes
- Keep going?

Pass 3

- CLOSE ATTENTION:
  - Thought experiment
  - Check all assumptions – any missing?
  - Check all details – any errors?
  - Limitations – any unidentified? How to address?
  - Important citations – any missing?
  - Think about future work

Questions to ask after reading the paper…

- Is the proposed approach a good one?
- Are the findings persuasive? Supported by enough evidence?
- Is there an alternative interpretation of the data not addressed by the authors?
- How does this relate to my work?

Takeaways from reading EVERY paper

- What did they actually do?
- What knowledge did we gain because of this?
- What assumptions did they make?
- What papers did they reference?
- What opportunities for future work exist?

Now that you've read the paper

- How do I store this paper?
- Should I use a template for my notes?
- How do I save my notes?

Sit down and write your notes

- As you're reading, take notes (a few sentences) about each paper
  - Method
  - Major contribution
- Bin papers by common theme
- Write a paragraph (or more) about each theme, citing the papers you've found.
  - Tie to your work

What is a Literature Review?

Introduction

According to the U.S. Department of Energy (DOE), "Increased R&D efforts and innovation will be required to continue to expand the wind energy industry" in the United States, where wind power is still a maturing techno… wind farm layouts is part of this R&… that the demand for energy will i… twenty years [1] with the intent of supplying 20% of the total electricity demand utilizing wind power. In addition, outdated means of energy development have been attributed to climate change, pollution, and permanent depletion of natural resources. These concerns have led to public demand for cleaner, sustainable energy sources like wind turbine technology. To meet these demands it will be necessary to ensure new wind farm installations are developing as much power as possible, which depends on the wind farm layout's capability to account for local wind conditions and aerodynamic interaction between turbines.

The complexity of the wind farm layout problem lies in the dynamic conditions of the farm site and the modeling available to represent realistic wind patterns and wake interactions. A turbine in wind will develop a turbulent wake that decreases the wind speed downstream. On a wind farm, turbines are typically placed in close enough proximity that the effect of placement in a wake could drastically reduce the effective wind speed to downstream turbines and therefore decrease their power output. Essentially, the goal is to incorporate as many turbines as possible while minimizing land use, without compromising the efficiency of the farm due to wind speed decrement from wake interactions. This work seeks to develop an optimization algorithm that will consider

Covers all literature *directly related* to your work

Previous Approaches

The first attempt at applying computational optimization algorithms to the wind farm layout problem was by Mosetti et al. [2], utilizing a genetic algorithm (GA). This preliminary study developed the framework that has been continuously used for comparison purposes, including the objective function formula and the use of the Jensen wake model [3]. Mosetti et al. used a discretized solution space of 100×100 cells and limited the placement of turbines to the center of each cell. The genetic algorithm considers each row of the grid as a binary string. A similar but improved GA approach was performed by Grady et al. [4] whose algorithm incorporated heuristic knowledge about wind farms and utilized more advanced computational resources. Two more recent studies, one by Wan et al. [5] and one by Mittal [6] improved on both previous genetic algorithm approaches by implementing a second discretization phase that allowed the turbines to be moved within their assigned cells. Though these works have advanced the study of wind farm layout optimization, these genetic algorithms may have been hindered by the inherent discretization of their binary

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Why Write One?

You have to.

Shows the need and novelty of your work (the research gap)

Gives reasons why you're looking at your research problem in a technical (not an impassioned) way

Your work needs a solid foundation in existing literature in order to be taken seriously.

Software for building a personal library

Compare Products	MENDELEY	EndNote	RefWorks	zotero	Papers
Basic software package (includes all features listed below)	Free	$250	$100	Free	$79
Free web storage space (online backup of your papers)	2GB	1GB	NA	300MB	NA
Reference/Document Management					
Organization of PDFs and other documents	✔	✔	✖	✔	✔
Citation Plug-ins for Word	✔	✔	✔	✔	✔
Citation Plug-ins for LibreOffice	✔	✔	✖	✔	✔
Annotations/Highlighting in PDFs	✔	✔	✖	✖	✔
Cross-platform synching across desktop, web and mobile devices	✔	✖	✖	✔	✖
Knowledge Discovery					
Free and open database approaching 100 million documents	✔	✖	✖	✖	✖
Personalized paper recommendations	✔	✖	✖	✖	✖
Readership statistics & community tags	✔	✖	✖	✖	✖
Open Web API	✔	✖	✖	✔	✖
Full text search across all your papers	✔	✔	✖	✔	✔
Search across external databases	Almost there!	✔	✔	✖	✔
Collaboration					
Private groups	✔	✔	✔	✔	✖
Public groups	✔	✖	✖	✔	✖
Social network	✔	✖	✖	✔	✔
Collaboration newsfeed	✔	✖	✖	✔	✖

Revisiting the research plan

Heilmeier questions

- What are you trying to do?
- How is it done today? What are the limitations of current practices?
- What is new in your approach and why do you think it will succeed?
- Assuming success, what differences does this make to us and society?

Heilmeier questions

- What are the risks, and what can we do about them?
- How long will it take?
- How much will it cost?
- What is the timeline and what are the deliverables that we should expect throughout the project?