Spring 2025

ME 794 Statistical Design of Experiments

Chapter 0 Introduction

Prof. Soham Mujumdar

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NOTE: Some of the course material is adopted from 'Design and Analysis of Experiments' by D. C. Montgomery, and similar courses taught by Prof. S. G. Kapoor at the University of Illinois at Urbana-Champaign and Prof. S. S. Joshi at IIT Bombay. You do NOT have permission to share this file or any of its contents with anyone else, and/or upload it on the internet or any of the platforms where it can be accessed by others.

ME 794 Schedule



Spring 2025, IIT Bombay

Time: Tuesdays and Fridays, 5.30 pm – 6.55 pm

F24, ME

Instructor:

Prof. Soham Mujumdar S23, Mechanical Engineering, sohammujumdar@iitb.ac.in

Office hours: By appointment

Grading Policy



Lecture Notes:

- Take your own notes
- Lecture notes/slides and reference material will be provided as and when required via MS Teams
- Join MS TEAMS using this code: 4jystcd

Grading:

• Quiz	(Best 4/5, preannounced , after every 4 lectures, NO MAKE-UP)
Assignments	(For your own practice, no grading)
Project	20% (Team project, actual physical experiments are expected)

• Final Exam 30% (Comprehensive)

- Quiz Dates: 21 Jan, 7 Feb, MidSem, 21 Mar, 8 Apr
- Projects: No simulations, data collected from internet/literature is acceptable. You need to design and conduct physical experiments on your own
- Any student/group found to have committed or aided and abetted the offence of plagiarism will receive ZERO marks for the relevant assignment/quiz without any exceptions

What is the NEED for experiments?

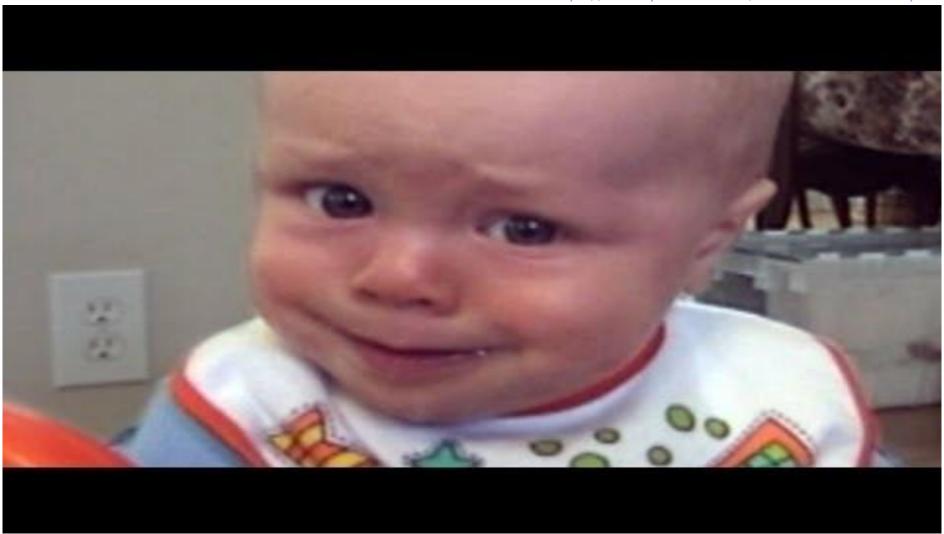


Why do we perform experiments? (scientific or otherwise)	MAC.
 Share what experiments you have performed or are currently planning 	

Example Experiment

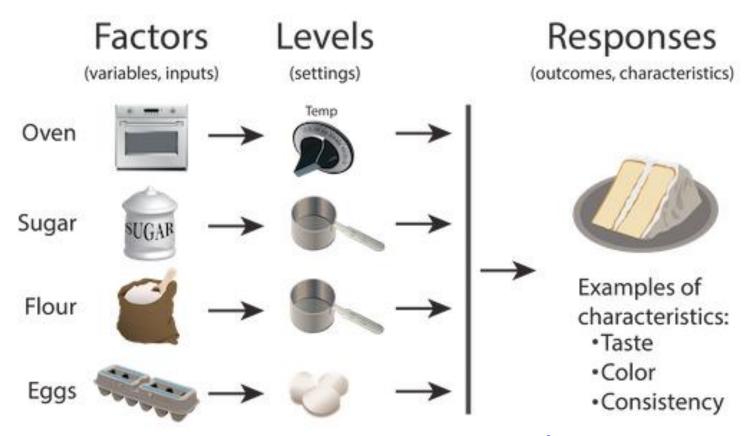


https://www.youtube.com/watch?v=XtcbRuuxXpA



Example Experiment





Ref: www.morestream.com

Need for Experiments



- To understand how a product functions or a process behaves
- To discover the direction of changes that may lead to improvements in both quality and productivity.

A fundamental task in designing a (scientific) experiment is to select an appropriate arrangement of test points within the space defined by the independent variables and develop a mathematical model

- For example, if a quadratic relationship between two variables is suspected, an experiment that studies the process at only two levels of these variables will be inadequate.
- Similarly, an experiment using four levels would be unnecessary and inefficient if the true relationship were linear.

Why Statistical Methods?

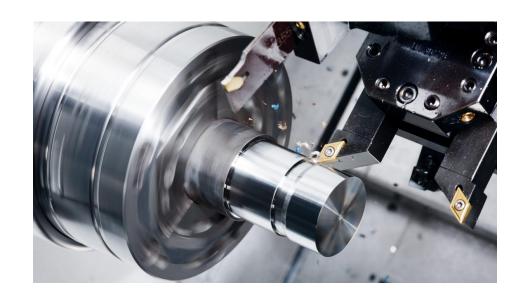


- The world around us is not deterministic! Variability is part of the natural order of things
- Variation in data is neither totally chaotic nor small enough to be ignored
- It is real, identifiable, and predictable statistically

What is variability?					

Example





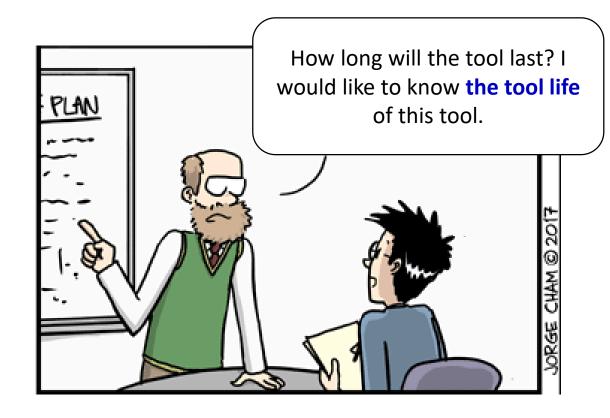
Turning operation under following conditions

Speed: 170 FPM

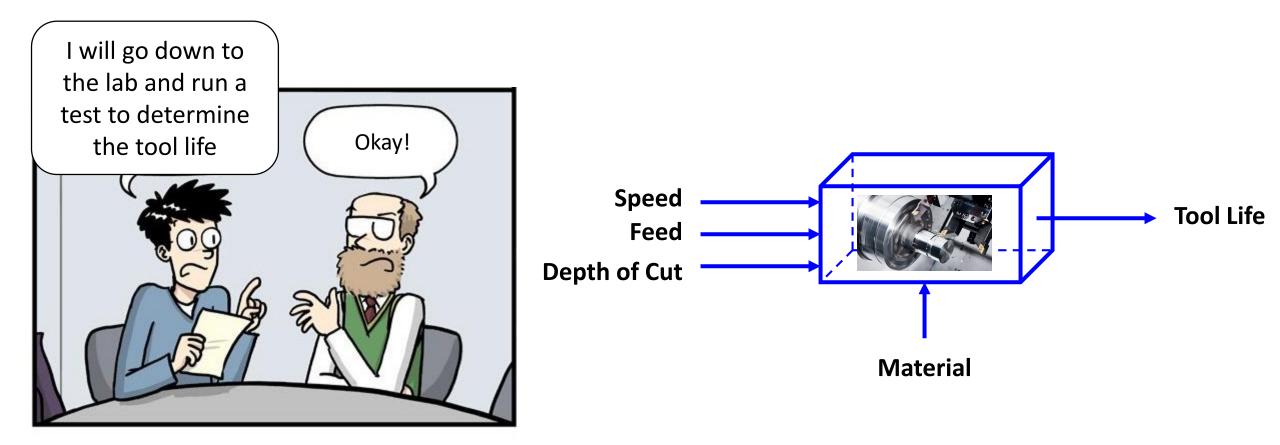
Feed: 0.017 IPR

Depth of Cut: 0.07 IN

Workpiece: 1018 Steel of 6 IN Dia, 24 IN Length









I have found the tool life to be **15 minutes** for the conditions you specified.

That's fine, but why don't you go back and run another test. I just want to be sure that the tool life is 15 minutes.



I already told you that the tool life is 15 minutes, but I will run another test if you insist!

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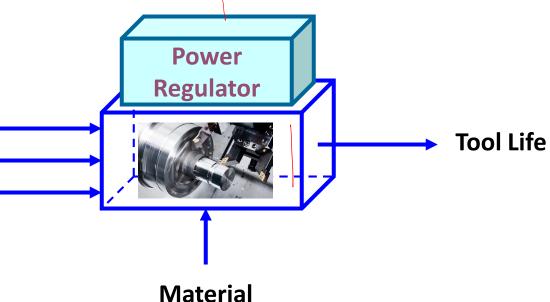


After running another test ...

Professor, this time I got tool life of **16.2 minutes**. But that's probably because of fluctuations in the machine power. If we install a power regulator, we can eliminate this source of variation, and get a true tool life value.

Sure. Do whatever you need to do and re-run the test.

Speed — Feed — Depth of Cut

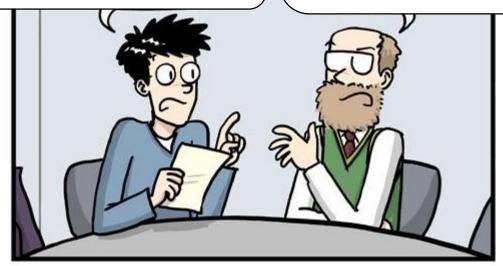


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After installing the power regulator, I now get **15.6 minutes**. This is the **true** tool life!

But what about machine vibrations? Was it vibrating during the test? Should you not make the machine more rigid and re-run the test?



Oh yes! You are right. I better make the machine more rigid.

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Now I get 16.2 minutes. I am sure that THIS is the true tool life!

How can you be sure you have eliminated ALL variation? What about difference in materials, tools, operator inconsistencies, etc.?





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What I really want is an average tool life for an average tool cutting a material over average environmental conditions. There will always be some variation in the process. We do the best we can!

Okay, I will run more tests using several tools, material pieces, etc. and find out what the average tool life is.



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I have run tests over random sample of tools, workpieces, time of day, etc.

Here are the results. I find the average tool life of 16.1 minutes



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Test #	Tool Life	Test #	Tool Life
1	15	7	15
2	15.6	8	16.7
3	16.2	9	16
4	16.5	10	16
5	16.2	11	16.7
6	16.5	12	16.8

Average of 12 tests = 16.1 minutes



That's fine, but how confident are you that 16.1 min is the true tool life?





That's not good enough. You better tell me something like "I am x% confident that true tool life is within certain range". Isn't that logical?



It certainly seems logical. But I don't know the answer!

Go and learn
Statistical DOE
and Data Analysis



Why Statistical Methods?



- The world around us is not deterministic! Variability is part of the natural order of things
- It is real, identifiable, and predictable statistically
- We can easily define many factors of potential significance but only a few accounts for the vast majority of the structure/variation in the data.
- But, the problem is to screen from a large group of potentially important factors those few, which are worthy of continuing study.
- All processes are subject to identifiable and unidentifiable disturbances which can totally invalidate results.
- The world around us is non-linear.



Experimental Error

- Composed of many minute disturbances which individually have little effect on the outcome of the experiment.
- Collectively these small chance occurrences may increase the dispersion or spread of the results to the point where real variable effects are masked
- Composed of more than errors of measurement not all instrumentation oriented. A good measurement system accounts for no more than 10-15% of the total error.
- Can be a function of both unknown and known sources.

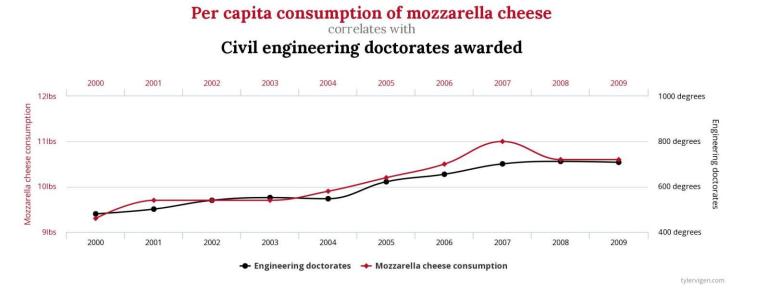
Here, statistical methods can help. They will tell us,

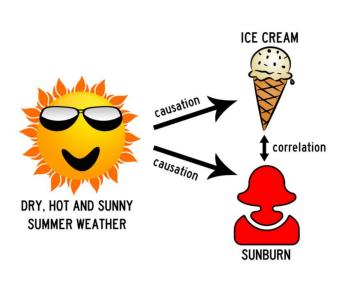
- Can the results be explained solely by chance causes?
- How much data is required to reveal the existence of true effects in light of chance error?



Correlation vs. Causation

- Two factors are highly related only because they are related to a third common (often unidentified)
 factor. Deliberate change in one may not lead to a change in the other- The concept of planned versus
 passively observed
- To really find out how changes in some factor affect the output, you have to change that factor deliberately and observe the change.







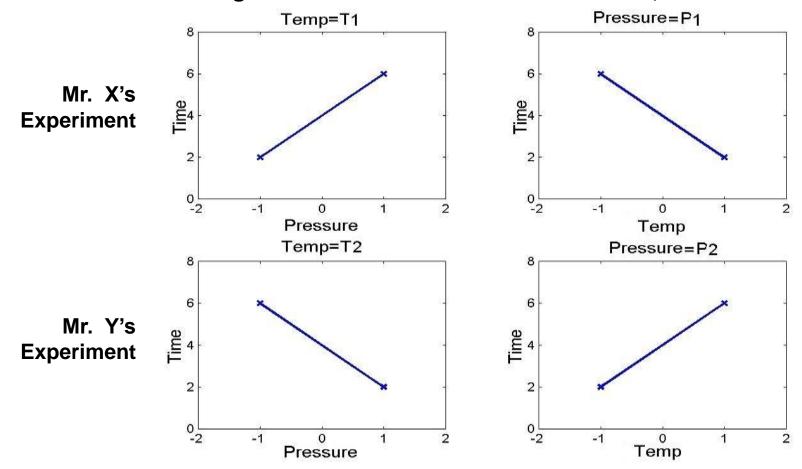
Complexity of Variable Effects

- Ideal scenario: variable effects are linear and additive! Generally not the case!
 - Example: Effects of aspirin and coffee on driving reaction time: aspirin increase Δ , coffee reduce 2Δ .
 - Will one aspirin and one cup of coffee reduce reaction time by 1Δ? Additive: Will 10 aspirins and 5 cups of coffee keep reaction time constant? Linear?
- Need to plan experiments to reveal variable interactions and nonlinear variable effects



Example of Variable Interactions:

Temperature and Pressure are thought to affect the chemical reaction rate/time



Why Statistical Methods?



- We know much less about what makes things work than we think.
- Experimentation is a costly and time-consuming business. We better do it right.

Statistical tools can help us navigate through experimental problems

A myth: "Everything he is saying sounds logical and probably works fantastically for some people – but my specific problem simply doesn't lend itself to this approach and/or simply doesn't need it anymore."