Course material

Course:

ENG606 / PHYS 442

Video:

DOE_Lesson3_part1_empirical_modeling

Concepts (extracted from automatically generated subtitles):

Small problem. Ideal things. First time. Design of experiments. Weak control. Man of experiment. Middle course. Islamic world. Conclusion validity. Start of the course. Different test of elasticity. Real world. Master project. Lot of elements. Founders of the occidental science.

to video sequence search
(within ENG606 / PHYS 442.)

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notes

summary

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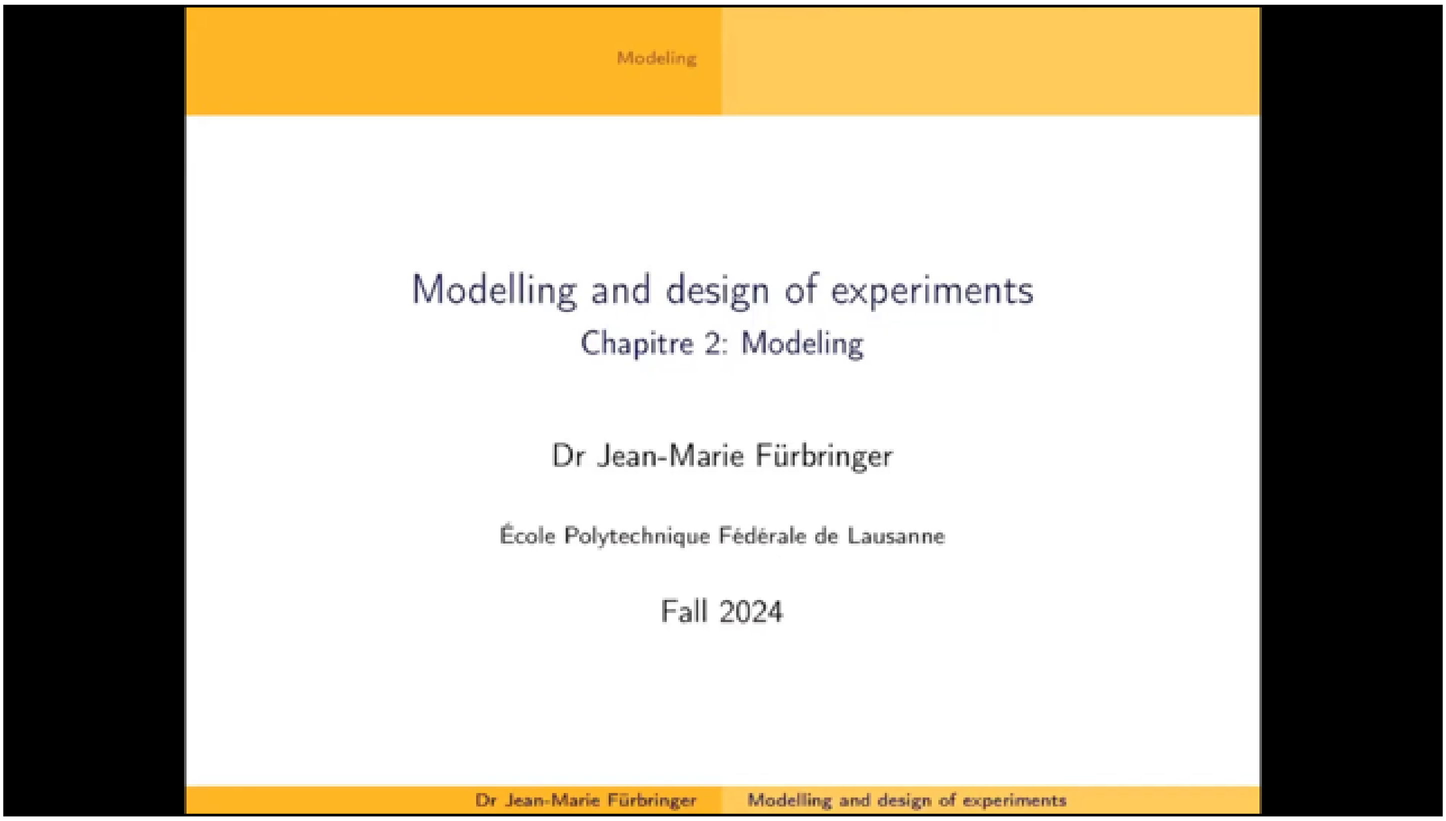

These subtitles have been generated automatically Today is quite an important lesson because we will see all the mathematical elements

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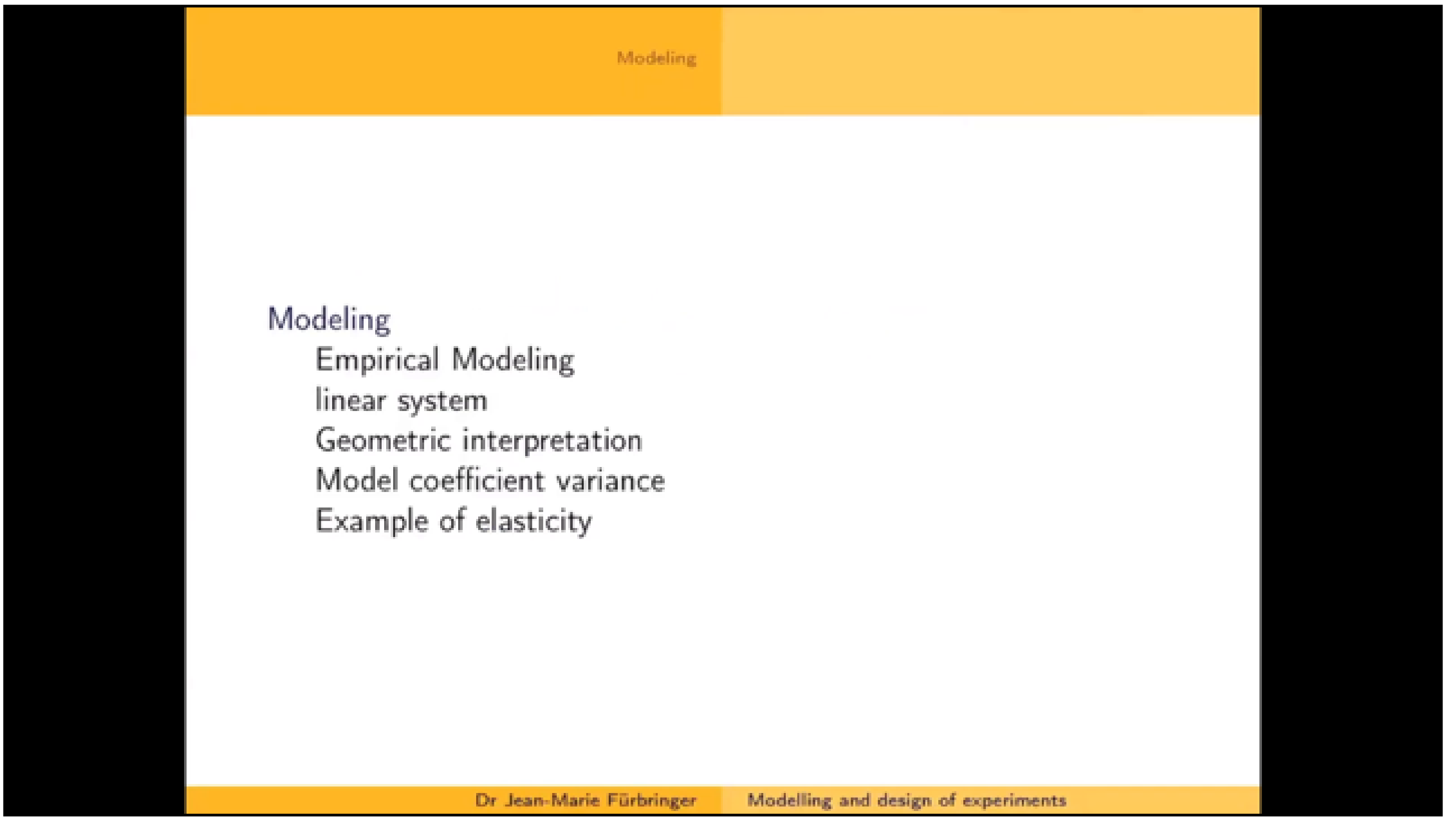

that we need for after optimizing design of experiments. So you will see the first time what we really call the design and after we will learn how to optimize a design.

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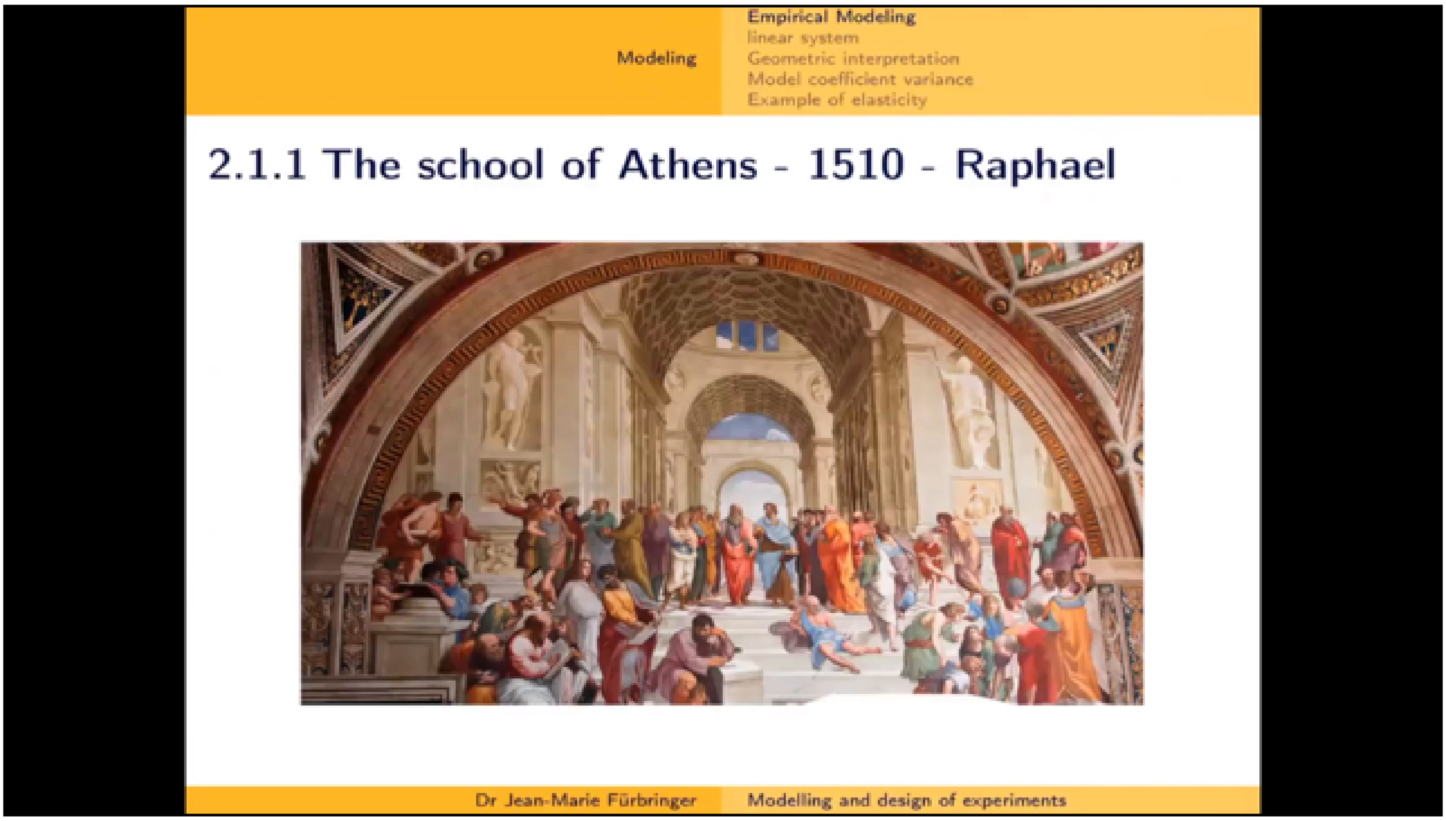

Sorry, there are a lot of elements. We will talk about empirical modeling, it's exactly what we are doing with the master project. After I will talk about linear systems, I will insist on the geometric interpretation of modeling. I will see you that in fact it's exactly the projection. And after we will see a few elements, model, coefficients, variants, so how what we are estimating is precise.

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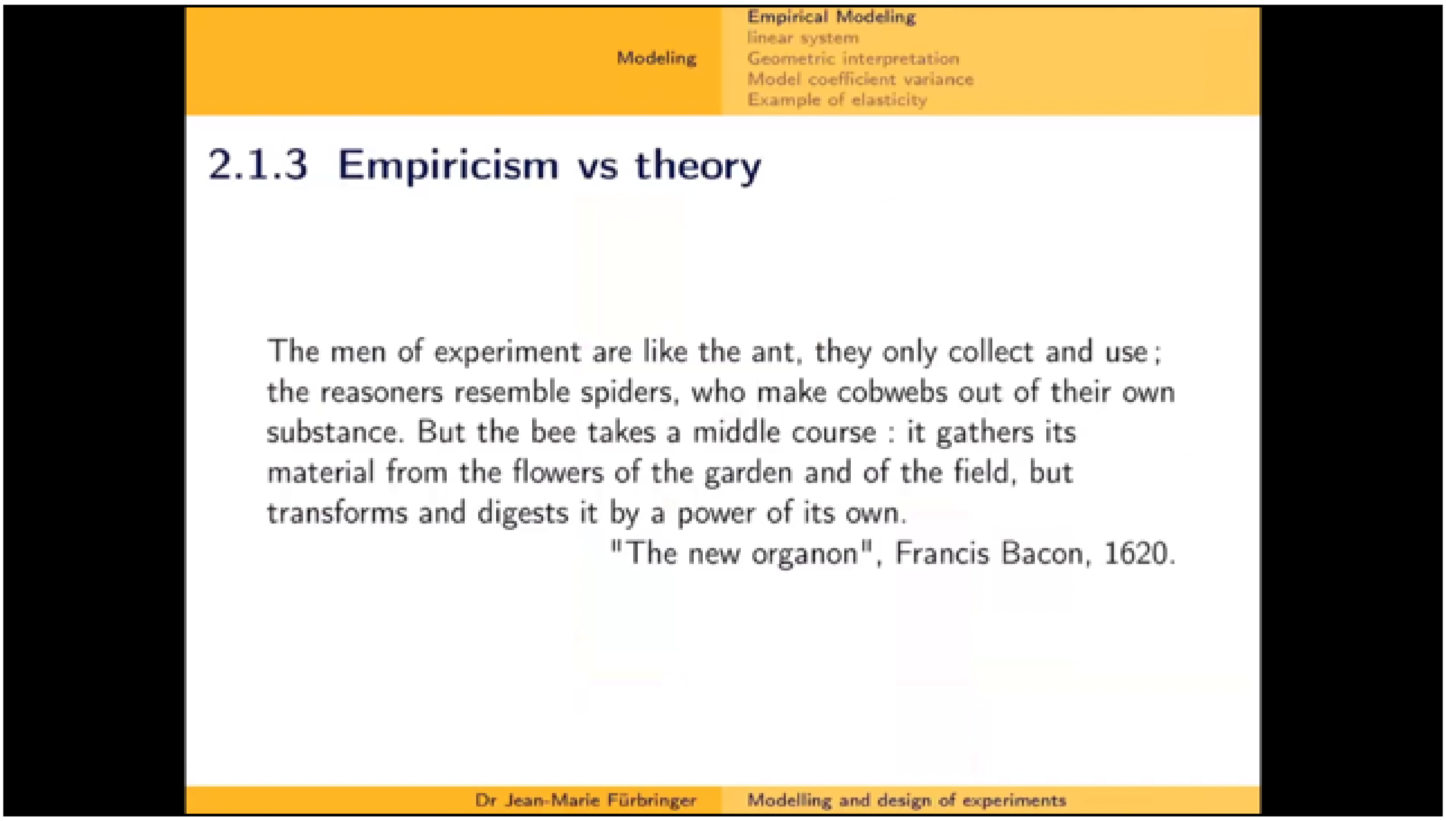

To start I wanted to show you this picture from Raphael. It's called the School of Assins and it has paint all the philosophers. And what interests us is what is at the center of the picture. It's two very important philosophers, Plato and Aristoteles. You know which one is Plato? Plato. He's the one showing the sky, because he was somebody, I don't know if you read a little bit of Plato, I probably read 10 lines of Plato when I was in high school. He was interested by the idea, the ideal things. You never have a triangle, because the figure usually never has the idea of the triangle, the definition of this triangle. So there's a difference between the reality and the ideal aspect. And Aristoteles is showing the earth, so it's showing things that must be concrete. Let's talk about things that are here. So why I appreciate this painting? Because in fact we have not to put them in opposition, we need both.

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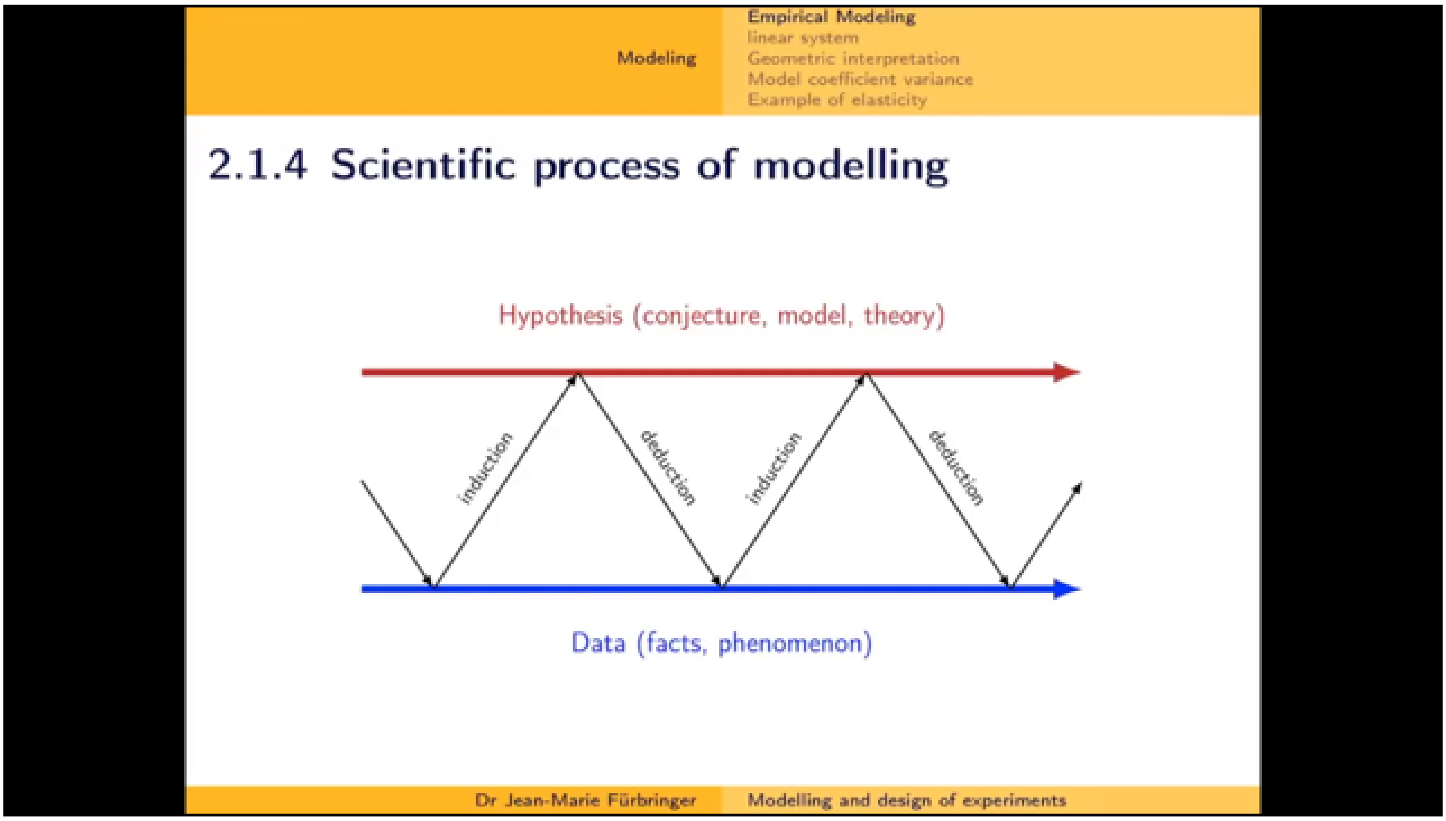

And this is the idea of statistics, is the idea of the alliance between Amperus and Cery. And this is from one of the founders of the Occidental science. So it's clear that, I don't know if you are aware of that, we present all the time, Occidental science as a success, but when we are just starting the base in North Africa and in the Islamic world, we're already making a lot of science, it's amazing, but sorry, my reference, Occidental, even if I know they are other very important in Egypt. Now you're from Egypt also, in Egypt, in those times, probably, I don't know, 300 years before they were already manipulating the concepts, coming from Chinese and India, but okay, Europeans like to present things like they invented everything, which is not the case. This is a very interesting text from Francis Baker. The man of experiment are like the ant. They only collect and use the reasoner, resemble spiders who make cobweb out of their own substance. That's the bee, so is the true extreme. But the bees takes a middle course, it gather its material from flower of the garden and of the field, but transform and digest it by the power of its own. So it's poetry, but don't fall in the trap, it's not exactly poetry. He's talking about what to use, to use ideas and to use things that are from the reality. So we will follow this middle way of the bees. So, and science is doing it and with success. So you have this, let's say, Greek theoretical way with hypothesis, conjecture, models, theory. We already know at that time that the earth was round there, made conjecture, and they were able to confront conjecture with some facts. So each time we have some facts.

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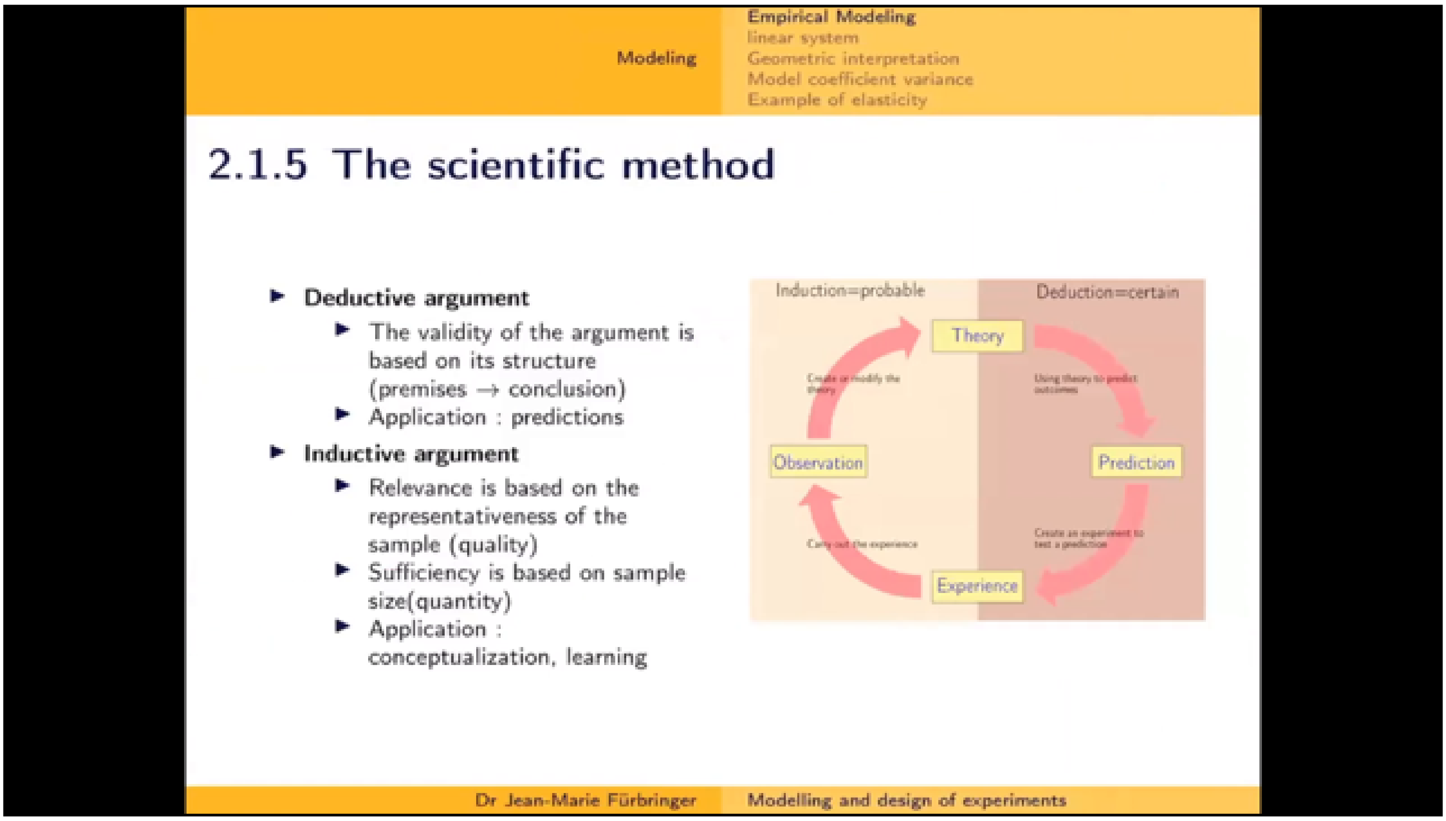

And so making science, in fact, is going from the blue to the red, from the red, from the blue. With what I find a small problem that usually if you follow a course of mass, a course of physics, a course of engineering, usually you have a professor coming, very good idea, but I'd stay here and explaining you and is learning you of making deduction. And when you go in an exam, give you a problem and you have to deduct from the things what you have. In this course, we are, in fact, training the other way around. We are training the induction. And it's the same. So it's black row, it's looked like, okay, it's another operation. But in fact, induction is a lot more complicating that deduction. Because in deduction, you have your element, your hypothesis, and sometimes, professor make a trap, or put more hypotheses that necessary. Sometimes you have less and you have to make some new hypothesis by your own, but typically it's deduction. And we are training people of making deductions. And you arrive at the master level, especially to the PhD level, and it's okay, you have learned a lot of things. And we are asking you to make the way in the other sense. It's not so easy. So design of experiment is exactly here for trying to helping you with your role of knowledge to arrive on the target is the objective of design of experiments.

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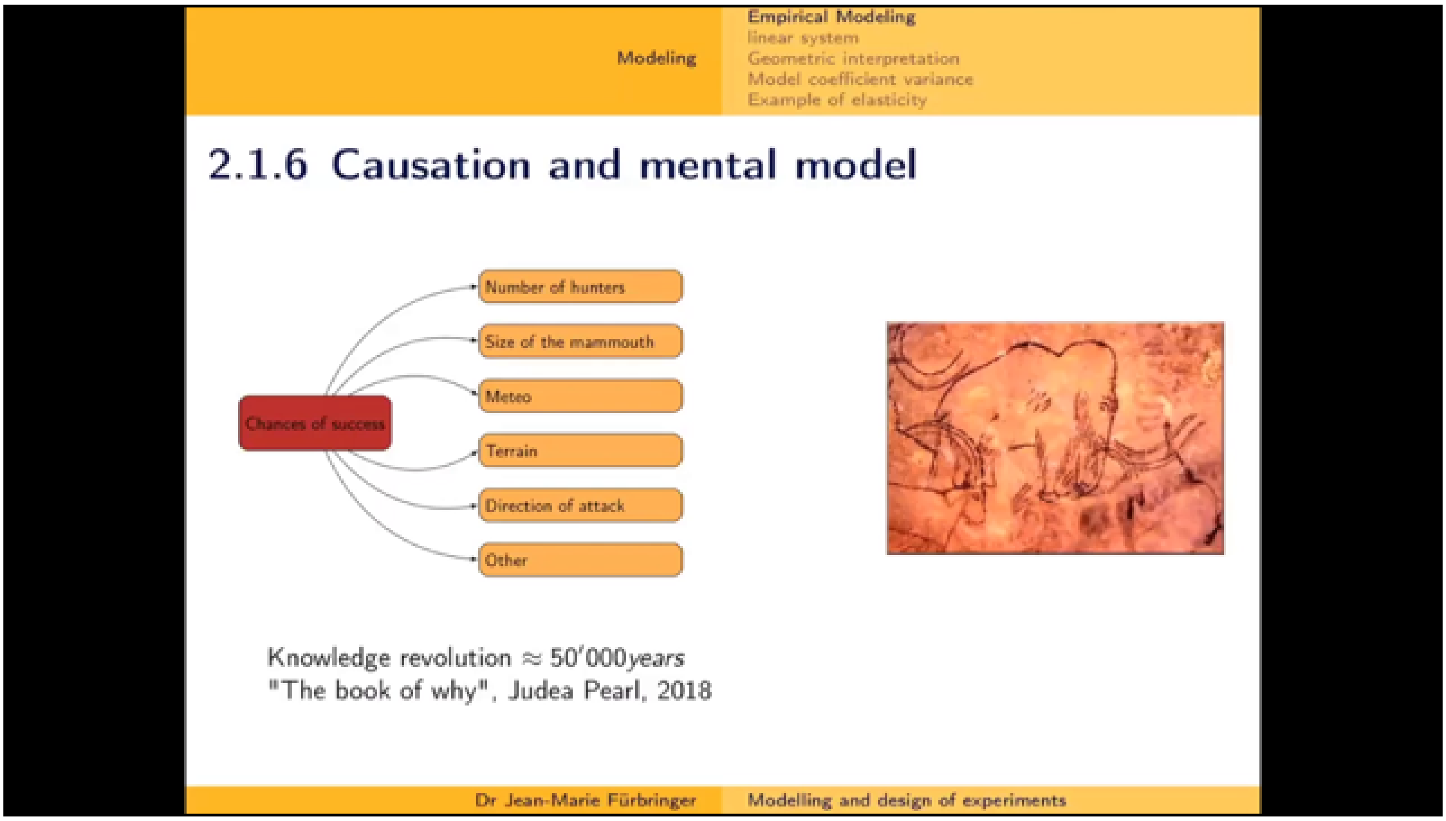

So this is what is called the circle of scientific methods with some deductive and inductive argument we need. So it's the same thing as the previous slide, presenting in another way, perhaps you see that more and more often. In here, you don't really see the progress, you just see the logic of the element. So usually it starts from observation. You see these, make some theory about these. And so you build a theory. And this is in fact the induction. And the problem of the induction that you don't know what you have taken, you observe a B. What do you have to observe from the B for make a theory on? There are a lot of facts which are the main difficulty. After when you have a theory, make a prediction. This is more easy because here you can use the logic. Going from the theory to the prediction is the logic, the pure logic. After you have to make experiments for checking for having facts. What we are doing in our master project, I really want you to do all the the circular one. And then when you have an experience, you need to make observations. And after you can confront and make a better model, so it's a sort of a virtuous circle. So this is what we call the scientific method. When somebody says, oh, something like that is, I don't know if you know, but what is mentioning is, but usually is considered as a scientific method. What is this example? All this is related to something I already mentioned. Is this cause and effect relation? So this is an example I take from an interesting book, Judy Appel, the book of why. It's very, if you want to go to the reading, it's very interesting. It is making all the book about the tradition of cause and consequence. And now it

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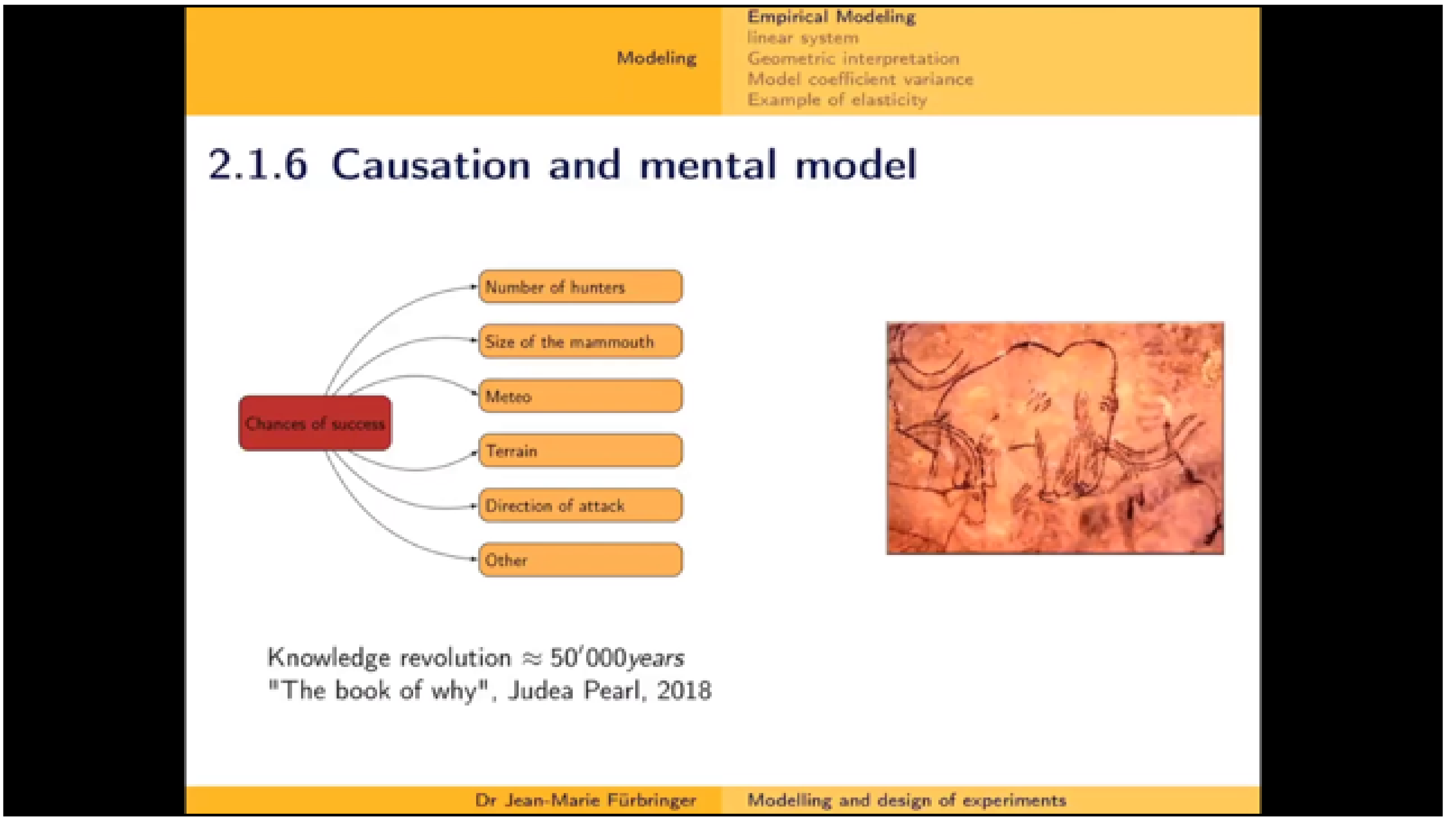

must be made correctly for avoiding the mixture between correlation and causation. So really how to do it. So if you have the opportunity to read the book, quite good. You can also look for a conference from him in YouTube. You find some conference. Just for let you understand what it's, and how it's very long in our history. So it's probably what we call the first knowledge revolution, probably 50,000 years we start to observe things. Imagine something as hunting a mammoth. What you need to plan. So that means that you are obliged to have a model. You cannot just go to hunt. And even is the question I have

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Brain Areas and Mental Operations

Mental Operation	Brain Area Involved
Environmental Scanning (observing weather, terrain)	Occipital Lobe (visual processing)
Risk Assessment (evaluating dangers)	Amygdala (fear and threat detection)
Strategic Planning (deciding on tactics, number of hunters)	Prefrontal Cortex (planning, decision-making)
Spatial Awareness (navigating terrain, positioning hunters)	Parietal Lobe (spatial reasoning)
Memory Recall (using past hunt experiences)	Hippocampus (memory formation and retrieval)
Coordination and Communication (organizing team actions)	Broca's Area (speech production) and Wernicke's Area (language comprehension)
Emotional Regulation (managing stress and motivation)	Anterior Cingulate Cortex (emotion regulation)
Predictive Modeling (anticipating mammoth ?s behavior)	Prefrontal Cortex (future planning)
Decision Making Under Uncertainty	Orbitofrontal Cortex (decision-making)

when lions go to hunt. Are they gathered all together? Because they don't send SMS and so they don't send text to us. So I don't know. So you have to sing to the numbers of hunters. So that means that you need to have an idea of the size of the mammoth of the size of the herd. You have to sing to the metal. So be careful when you go in complicated place with bad weather. I had my accident two weeks ago exactly because the weather was very bad. So you have to imagine the terrain. I don't know what you know about the hunt. It's not the subject of the curse, but usually they push the animal against a reef. It's one of the techniques of killing this very huge animal. How to direct the attack and etc. So very soon in the humanity we have developed models and we need to make all the time a model.

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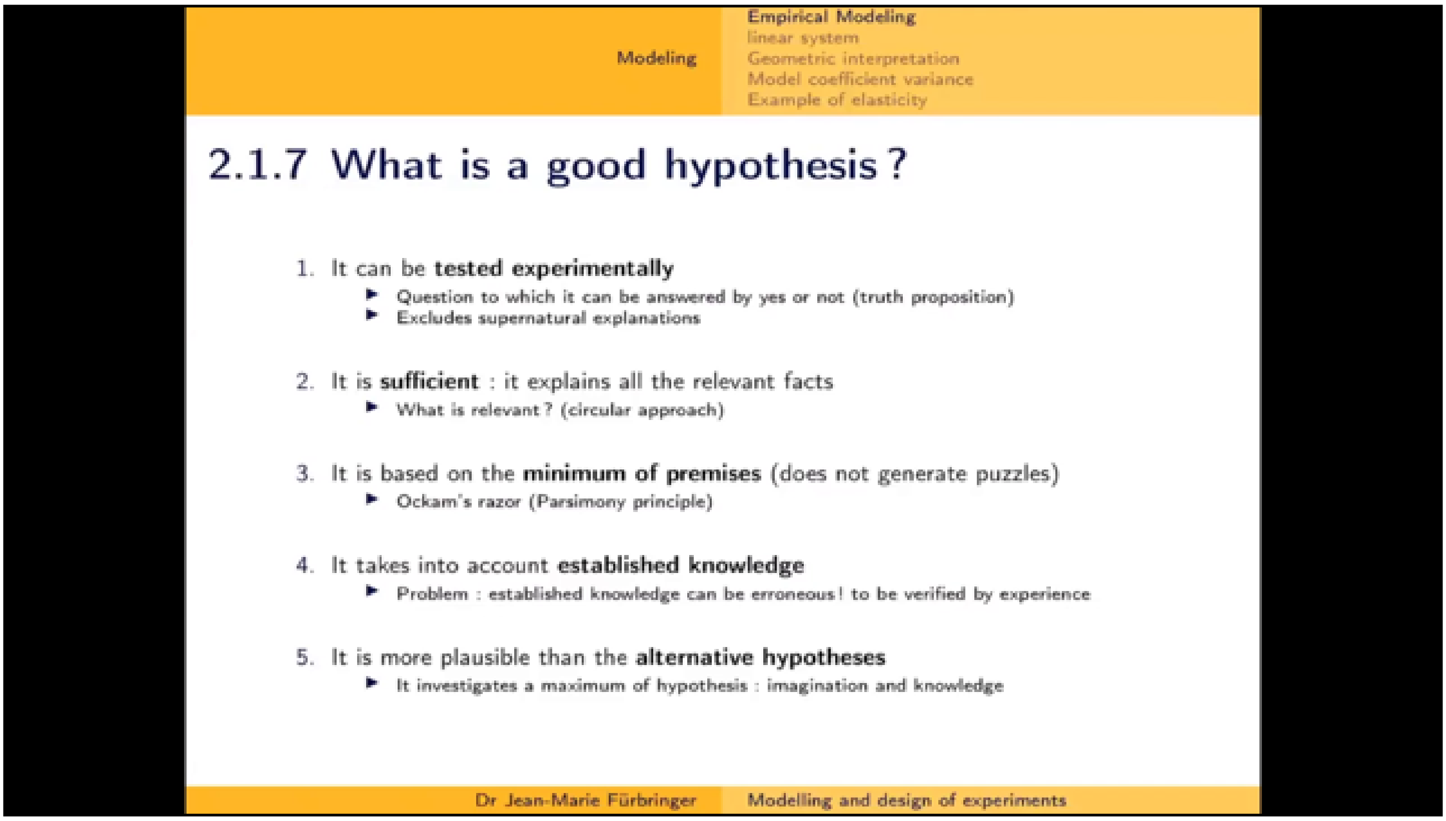
10m 25s



So there are a lot of mental operation. And this is, this is a study that will help me to make these slides is your mental operation. And you see that in your brain you are doing. And we will, sometimes we ask who talk about, the lady there talk about artificial intelligence. Now we would like to have the machines making some of these operations but it's quite very, very complex. So this is just by interest. It's not exactly the base of the curse, but imagine all the things that you have to see. You have to scan the environment. You have to think to the risk. You have to make some strategic planning tactics etc. You need to understand our things, where the animal will move etc. So understand the space. You have to remember some, some, some preview things. So this loop that you go again and again for improving. You need to coordinate and to communicate. You need to be, I like this emotional regulation. Imagine when the animal is arriving against you, you better rather than panic. And so you need predictive modeling and decision making under the intelligence. These are all the brains. In fact, now we are trying to make machines. They do that and statistics is very key in this element. So if you are interested in my wife, like lots of brain and everything that's happened, it's happened in the brain etc. So we need to make hypothesis. So what is a good hypothesis? This is very important. It's sometimes also the discussion between scientific approach and non-scientific approach. Typically, the magic approach is not exactly in this and this. So a good hypothesis, it can be tested experimentally. It's what makes science. Something that you cannot make an experimental. After we have to talk about what is experimental, but you don't know. Test experimentally is not really what we

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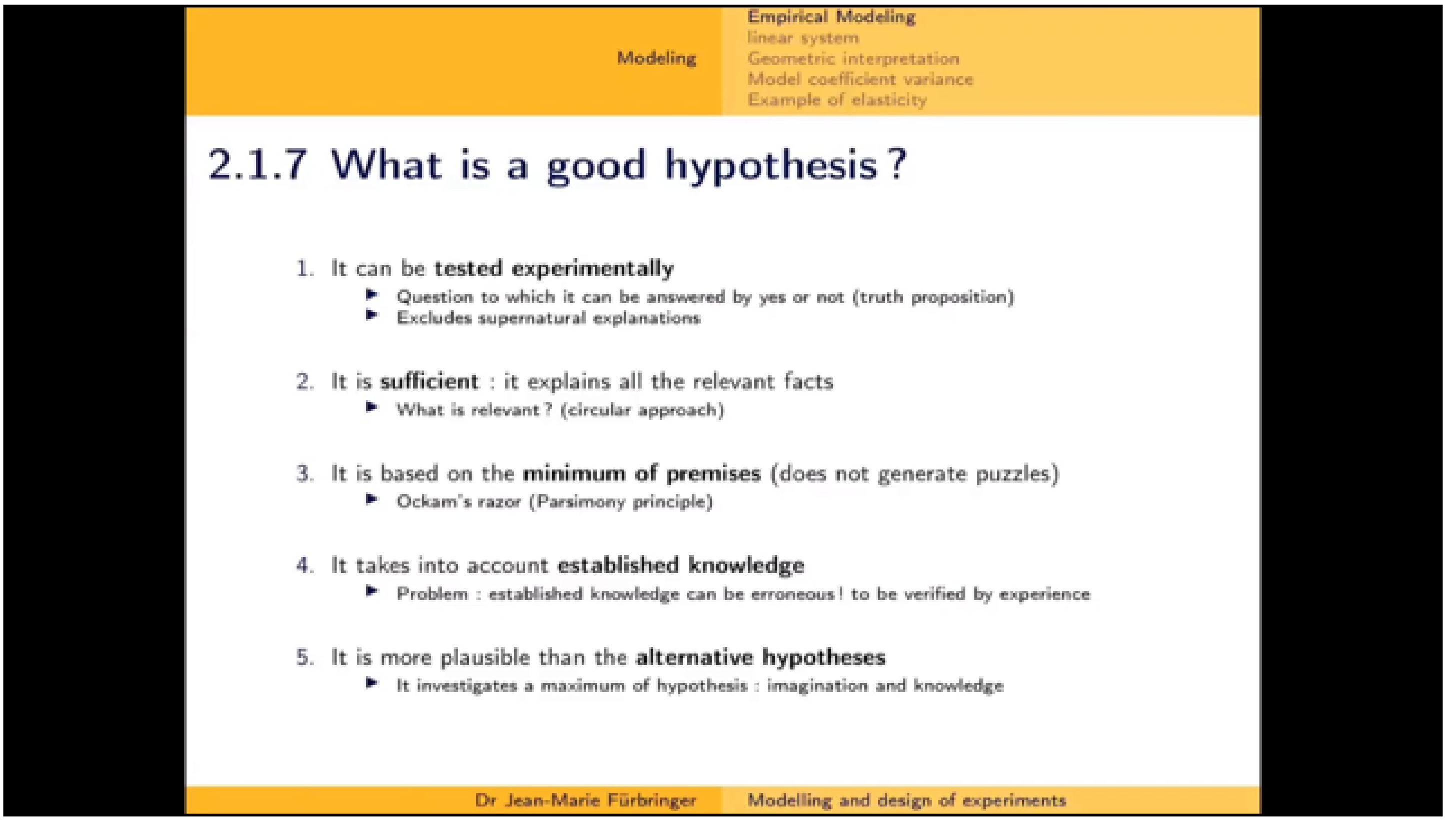

can call science. Question to which it can be answered by yes or not. It's work or it doesn't work. It's fail or it's success. Excludes supernatural explanation. Very rapidly, it was the question. We were in a really juice world and people have ideas, the magic projection of the world. Science exclude. I don't know if you remember this say about Laplace who made Celestial the mechanic of the sky and presents the work to Napoleon and Napoleon say that in your book, very interesting, but you never talked about God and you say, I didn't mean about this hypothesis. It must be sufficient. So it's explained all the relevant facts. So there is something sometimes we forget. Because it was an approximation of be careful because some detail could in fact invalidate your model. In fact, we appreciate to make a minimum of premises. We call that the OCam's razor. The fact that if there are an hypothesis not necessary, let it pass. For the project with the master student is exactly we try to model a device and what type of model do we need and why we use a simple squad. And this porcimony principle is very interesting because it's the position of scientific to say the reality we never manage it completely. But let's make a model of the reality.

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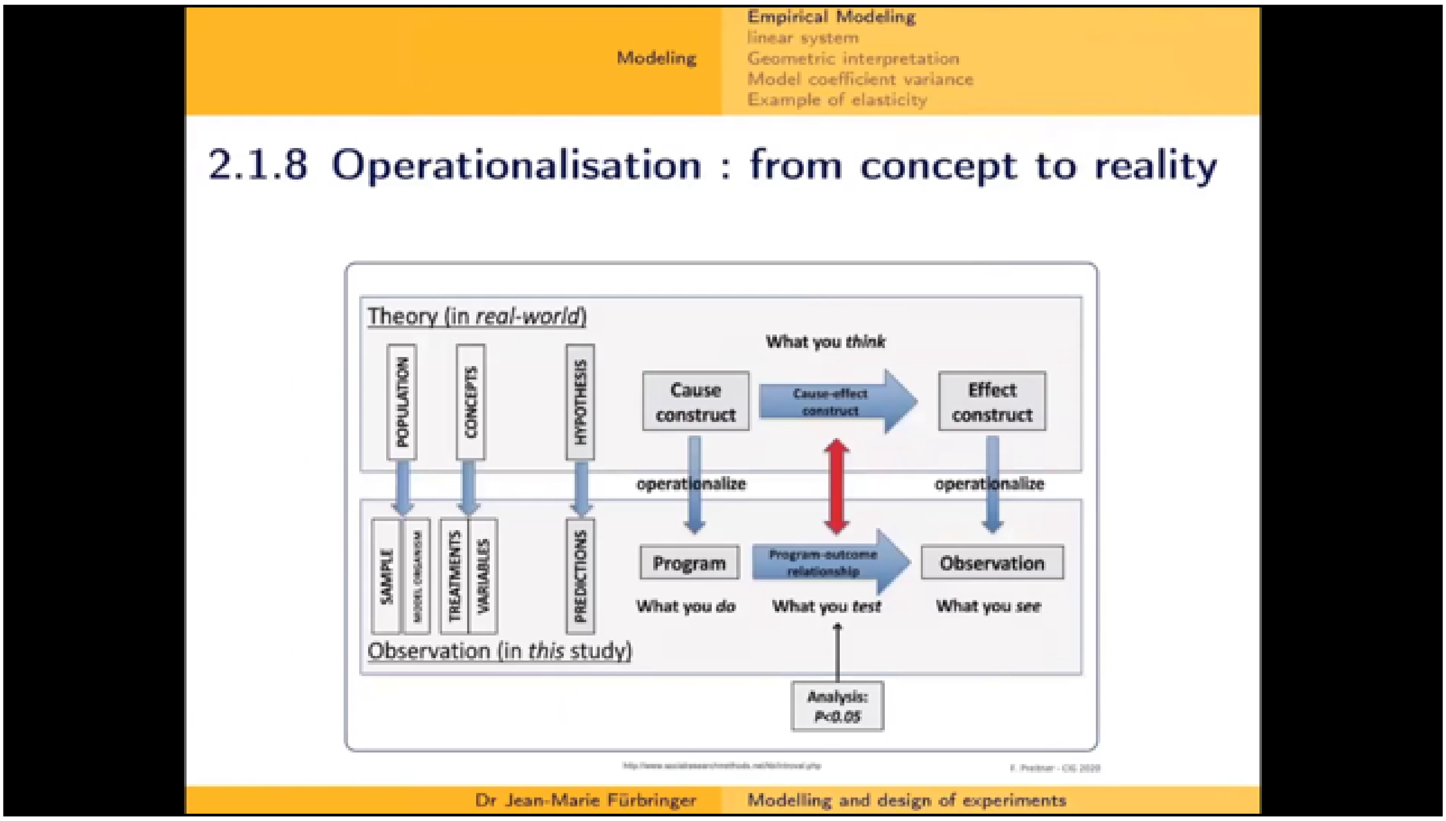

Let's make a map of the reality. But do not confound the map with the territory. Usually also you would like to consider that what have been known till now. You don't question it. If you question it, sometimes it's a review. When Einstein made his new theory, he didn't negate what Newton has done. Just integrate it and see it in another perspective. But you have to consider what he's already known. Well, there are sometimes different possibilities. And you have to balance between the different hypotheses because it could be different. A better example would be for fluid mechanics. You can have you can follow the flow or you can stay in a position. And so this is very two different hypotheses, different way of describing things. Hopefully they coincide, but sometimes you can make hypotheses that will not coincide and thought of biology. There are a lot of hypotheses that was opposing one to the other. And when we talk about lights and is light matter, is light a wave. And you know, this story, I don't want to tell it again. But you see, and finally we obtain something. In hypothesis, it was very strange. It's both.

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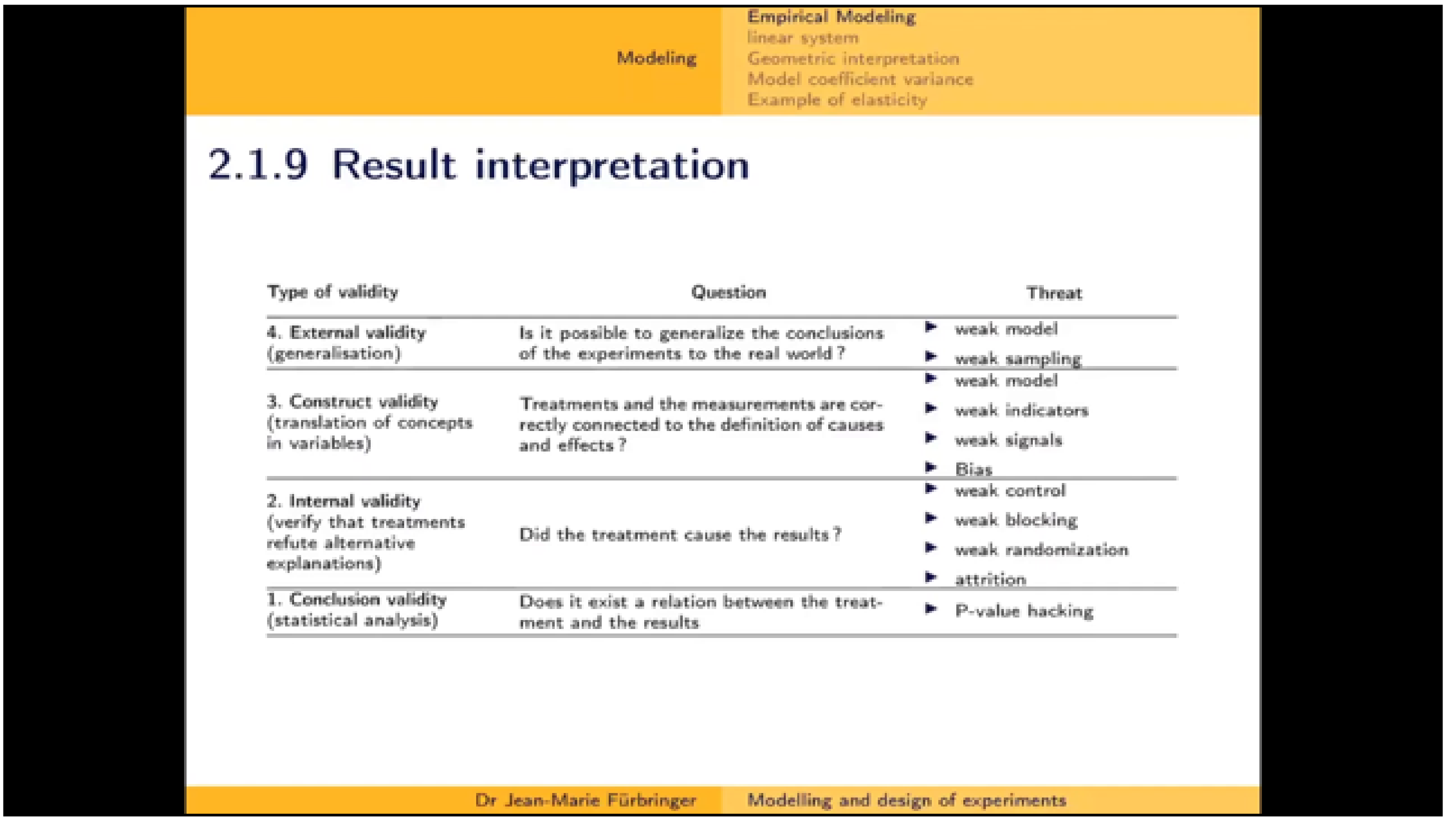
15m 37s



It happens sometimes. After there are also an element I would like to precise on the when we are making experiments. They are we are making theory for the old world. We are pretending, explaining not only what you have here now, but we would like to explain what we have now as just an example of what exists in the in the world in the universe and the reality. So this is the way of presenting this relation between what you are doing in your observation and what probably exists in the real world. So in the real world, you have the population of the events. It's something more easy to comprehend in biology, but in physics and engineering also, there are all the reality, all the cases that are possible. And you are sampling. So the sampling is very important to have it clear and are we measuring only which part and the sampling must be correct. After there are the concepts we are using and with from the concepts are related in our observation to the treatment and to the variable. The treatment and the variable are related to your concept. And after you have your hypothesis for what is the reality and in the observation, you have the prediction. You see that each thing has a correspondence in the real world or in your laboratory. So let's say that this is your laboratory, this is the world. After you need to make a program because you are thinking to a causation relation between your variable. And after you will make some observation and you have an analysis of your observation and you would like to conclude on something. There are some words we call operationalization. So it's a way of you pass from the real world to your laboratory and you go back to your laboratory to be sure that the experiments you are doing are

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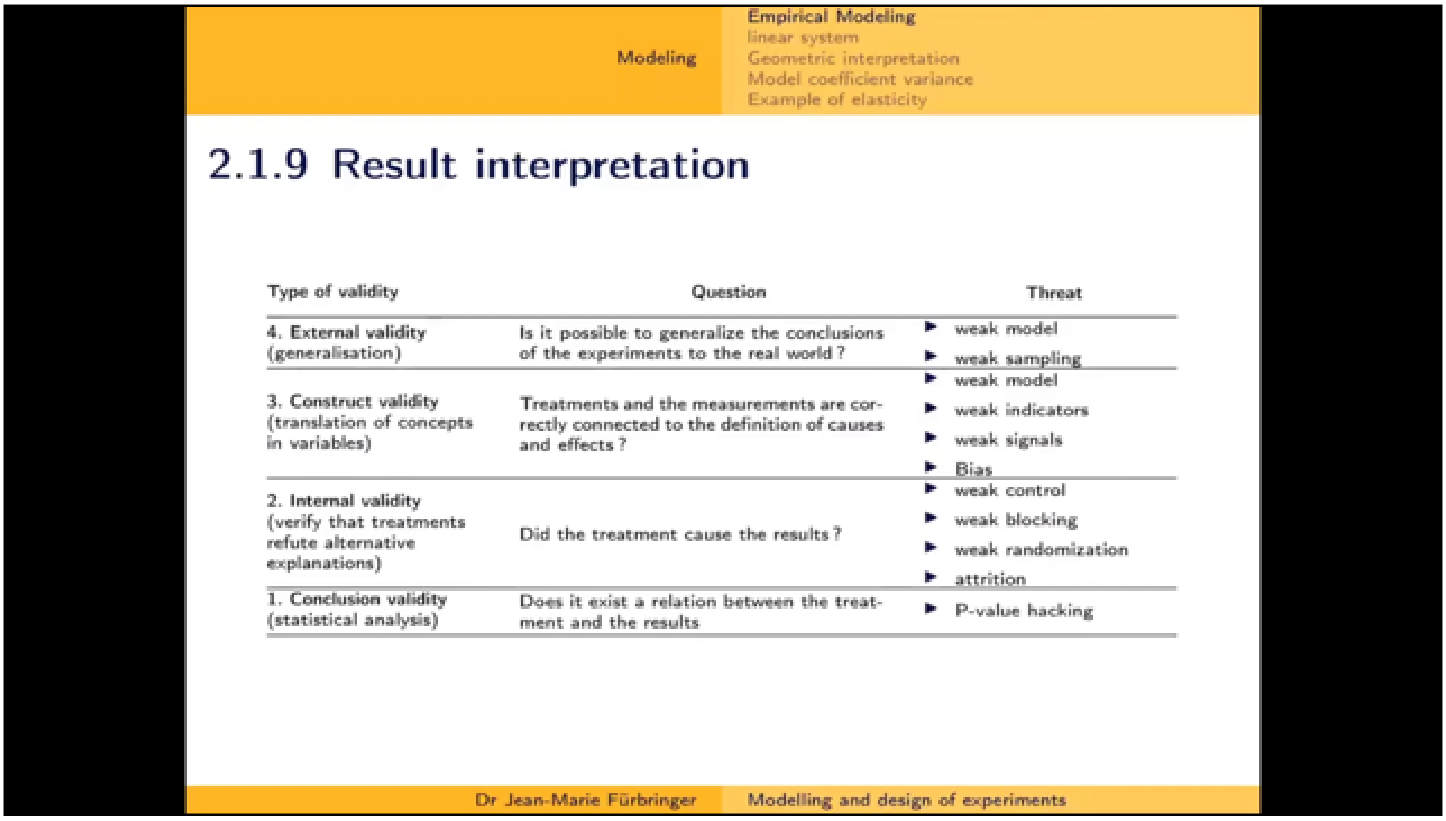

really representing what happened in the real world because your laboratory is interesting but what interests you is to understand the real world. And so this is a slide I said it's perhaps too early but I presented because it's logical now. So when you are making conclusion, you really need to make this to make clear this operationalization and check it's correct. So there are four points when the PG student when I will read your reports, I will make you comment from that. It's really my analysis, my scheme of analysis I'm taking important. So the first thing is the conclusion validity. So within your report is logical what you are saying. Are you making the correct operation 1 plus 1 equal 2? If 1 plus 1 equal 3 probably it could be a problem of conclusion validity. You make an error in the logic of your disposal, the logic of the treatment. And the big problem here is something we call the p-value hacking. In engineering it's not so much a problem because we usually make experiment not observation but in observations the p-value hacking is when you is a cherry picking you just understand that you have small effect and you make sufficient experiments so that finally you see that your effect is correct. But if you make a general sampling you will not see this effect. A second problem could be the problem of internal validity. You have to verify that the treatment refutes alternative operation. So you see something you obtain you make a vaccination that is the problem of the example of the treatment for men and women I presented is the first week. Are you really sure that it's a treatment which is curing those people? So those examples are really for life science a lot. In engineering honestly we usually do it things a little bit easier because we are manipulating

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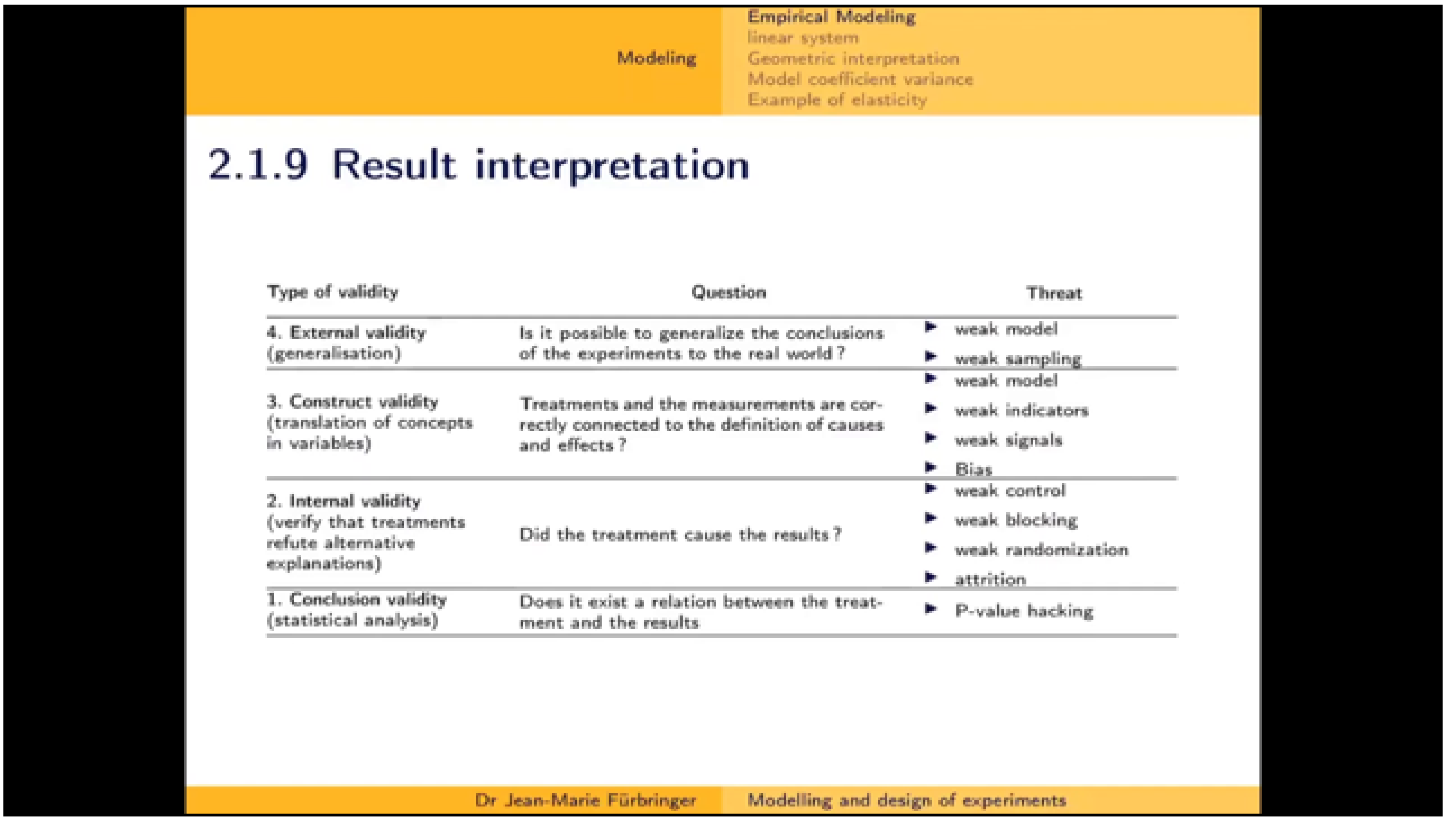

Type of validity	Question	Threat
4. External validity (generalisation)	Is it possible to generalize the conclusions of the experiments to the real world ?	▸ weak model ▸ weak sampling
3. Construct validity (translation of concepts in variables)	Treatments and the measurements are correctly connected to the definition of causes and effects ?	▸ weak model ▸ weak indicators ▸ weak signals ▸ Bias
2. Internal validity (verify that treatments refute alternative explanations)	Did the treatment cause the results ?	▸ weak control ▸ weak blocking ▸ weak randomization ▸ attrition
1. Conclusion validity (statistical analysis)	Does it exist a relation between the treatment and the results	▸ P-value hacking

our parameters. So be careful that it's really your parameters that are making your answer. It's not because you have the window open as a window closed or it's a difference of laboratory it's a difference of operator that in fact explain what's what's happened now. If you are in the prime of correlation no if you are measuring the efficiency of a solar panel when it's cold and rainy and when it's dry and hot you will not be able to see if the effect is because of the temperature of the effect is about humidity. So you really need to understand in the master project some of the students see the resistance moving a lot. So what is the code of that? Is your manipulation or is something I don't know that concretions and looms which is going up etc. So is the internal validity after? Oh and so the problems would be all the threats the risks are the fact that you you don't control your experiment sufficiently it's a weak control. We're weak blocking so weak blocking is typically you have a haven't you have to treat your samples and you put all the samples related to one answer in one definite one moment but the rest in another one so you never know if you so it's a good blocking would be to to make things correctly so that it's not the time you put things in the haven which is not the objective of your your study is not changing your your experiment or you have two operators one checking the yes answer and the other checking the no answer you will never know if it's the operator weak blocking weak randomization so you understand it so that means that you have impressions that you pick things at random when it's necessary to pick it at random and in fact you are following the

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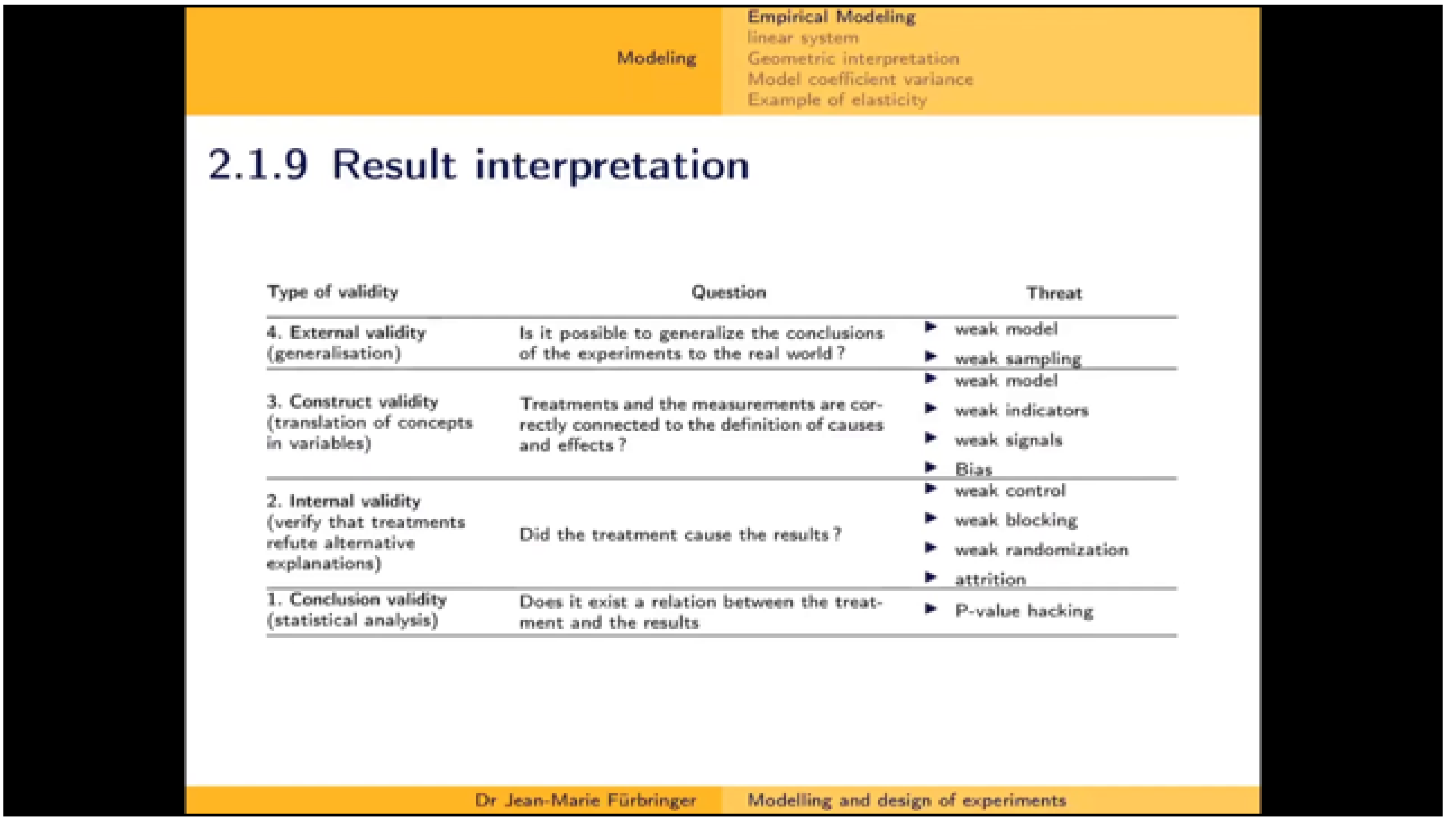

2.1.9 Result interpretation

Type of validity	Question	Threat
4. External validity (generalisation)	Is it possible to generalize the conclusions of the experiments to the real world ?	▸ weak model ▸ weak sampling
3. Construct validity (translation of concepts in variables)	Treatments and the measurements are correctly connected to the definition of causes and effects ?	▸ weak model ▸ weak indicators ▸ weak signals ▸ Bias
2. Internal validity (verify that treatments refute alternative explanations)	Did the treatment cause the results ?	▸ weak control ▸ weak blocking ▸ weak randomization ▸ attrition
1. Conclusion validity (statistical analysis)	Does it exist a relation between the treatment and the results	▸ P-value hacking

variation of one of the parameters so you never know if it's the time I don't know oxidizing your your element or it's really a different experiments that are responsible of the change because your randomization is not real. So it's never. Yes? So randomization is never random. No randomization is never exactly but you have to make as as you're not sure I understand your question so you mean. I think we uh when the variation we still follow some of the parameters so it's all you see. No no you have to avoid to follow what I don't what to mean follow I was following the increase of one parameter the decrease of one parameter. You will see in factorial design when we build the factorial design we the first column usually is minus and after it's plus so if you realize you're feeling like that that means that in the first period you have all the plus answer and after all the minus answer imagining that you have I don't know a device which is starting to heat up so the effect of this heat up will be mixed with the effect of the plus minus situation of one factor. Okay we got it? Follow up question. But if you are studying most likely it has the rest of the sort of distribution can you randomize this distribution somehow? No it's the sampling that you have to randomize so there's a thing that you should not measure. There's one parameter it's very typical when you have more than one parameter. One parameter you should not start by making the measurement as low value and after you go up and up we all do that but in fact it's not randomization you should make measurement at different values at random to be sure that your model is representing what's happened when you make a measurement at that value

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2.1.9 Result interpretation

Type of validity	Question	Threat
4. External validity (generalisation)	Is it possible to generalize the conclusions of the experiments to the real world ?	▶ weak model ▶ weak sampling
3. Construct validity (translation of concepts in variables)	Treatments and the measurements are correctly connected to the definition of causes and effects ?	▶ weak model ▶ weak indicators ▶ weak signals ▶ Bias
2. Internal validity (verify that treatments refute alternative explanations)	Did the treatment cause the results ?	▶ weak control ▶ weak blocking ▶ weak randomization ▶ attrition
1. Conclusion validity (statistical analysis)	Does it exist a relation between the treatment and the results	▶ P-value hacking

one time not when you remember this joke at the start of the course no it's a character that's throw the stone through the metallic arc and obtain a stone at the end and the conclusion was oh I get what I have in the initial but it was not the same at the end you have a stone you don't have what you get when you throw a stone you have a stone when you get the human you get a stone. This is randomization an attrition I don't remember

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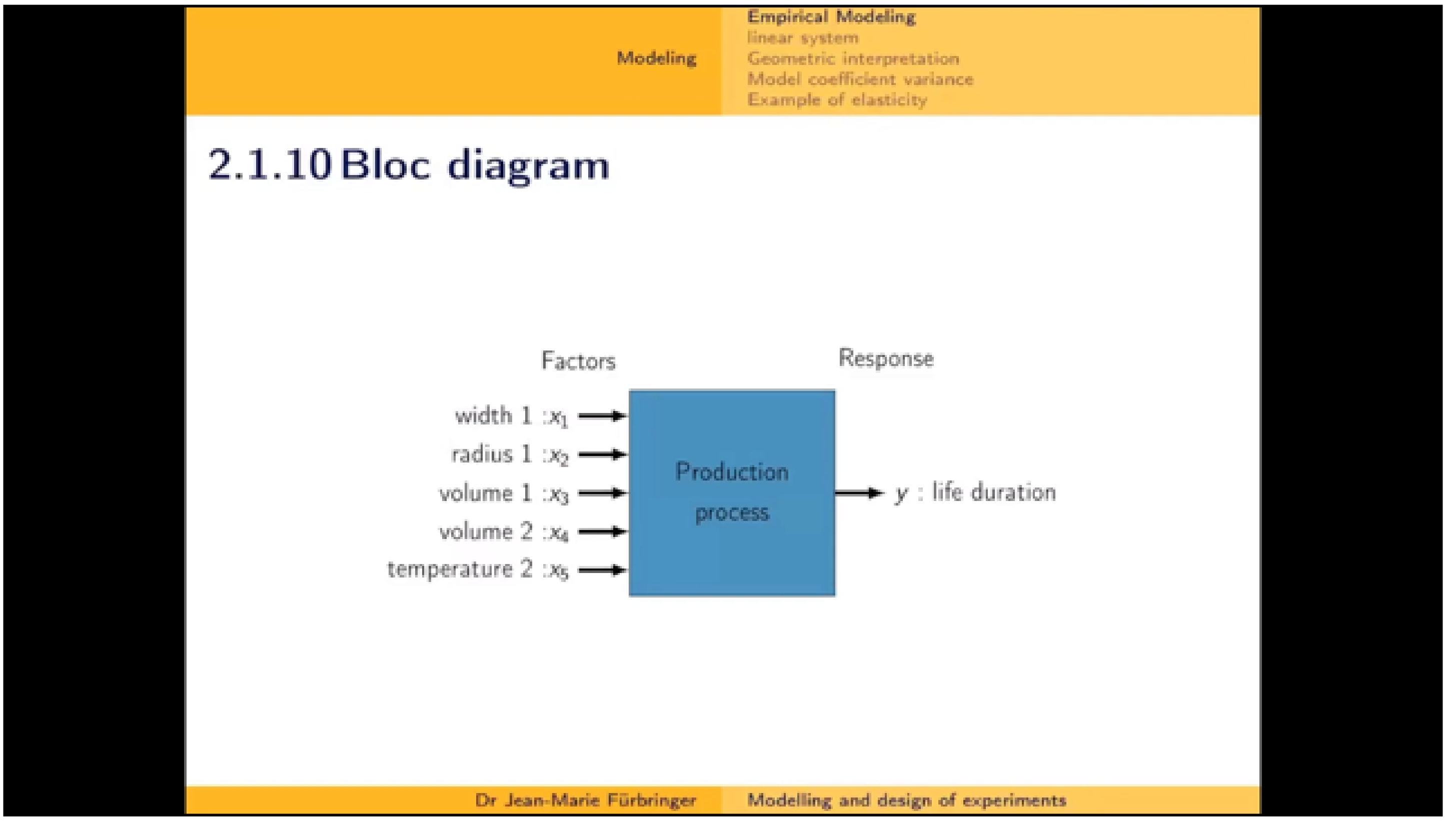

look I don't remember what is attrition that yeah it is more in medicine attrition is the fact that you have it's happened in some socio-economical analysis a lot usually not so much in engineering the fact that you are losing samples with the time because some sample breaks some sample you know patient died or patient go away or so attrition is the fact that you had make your experiment at the start you want 500 person and at the end you have five because this is attrition. After you have what we call the construct that validity is a translation of the concept in variable so again you were interested you will see the example of checking the quality of a steel for building a bridge and so you check the elasticity but is elasticity the only concept for qualifying the steel or you should test other things and how do you test elasticity there's this different test of elasticity so this is the problem of construct validity you are having the real world you want the good steel for what you want to do for making a bridge and after you are making experiment you are testing things you are testing the sanity of a product people eat no an E 264 I don't know a product and you are testing if it's a poison or not are you test that perhaps you test this with this mouse but perhaps the mouse are not reacting exactly as a human are reacting or very typical things between woman and man there are a lot of tests are made with man because okay you understand the medic with man and it's no nouns that's the medicine of woman is a little bit it's not at the same level because it was typically the construct validity they see man and woman and they just test on man what could be

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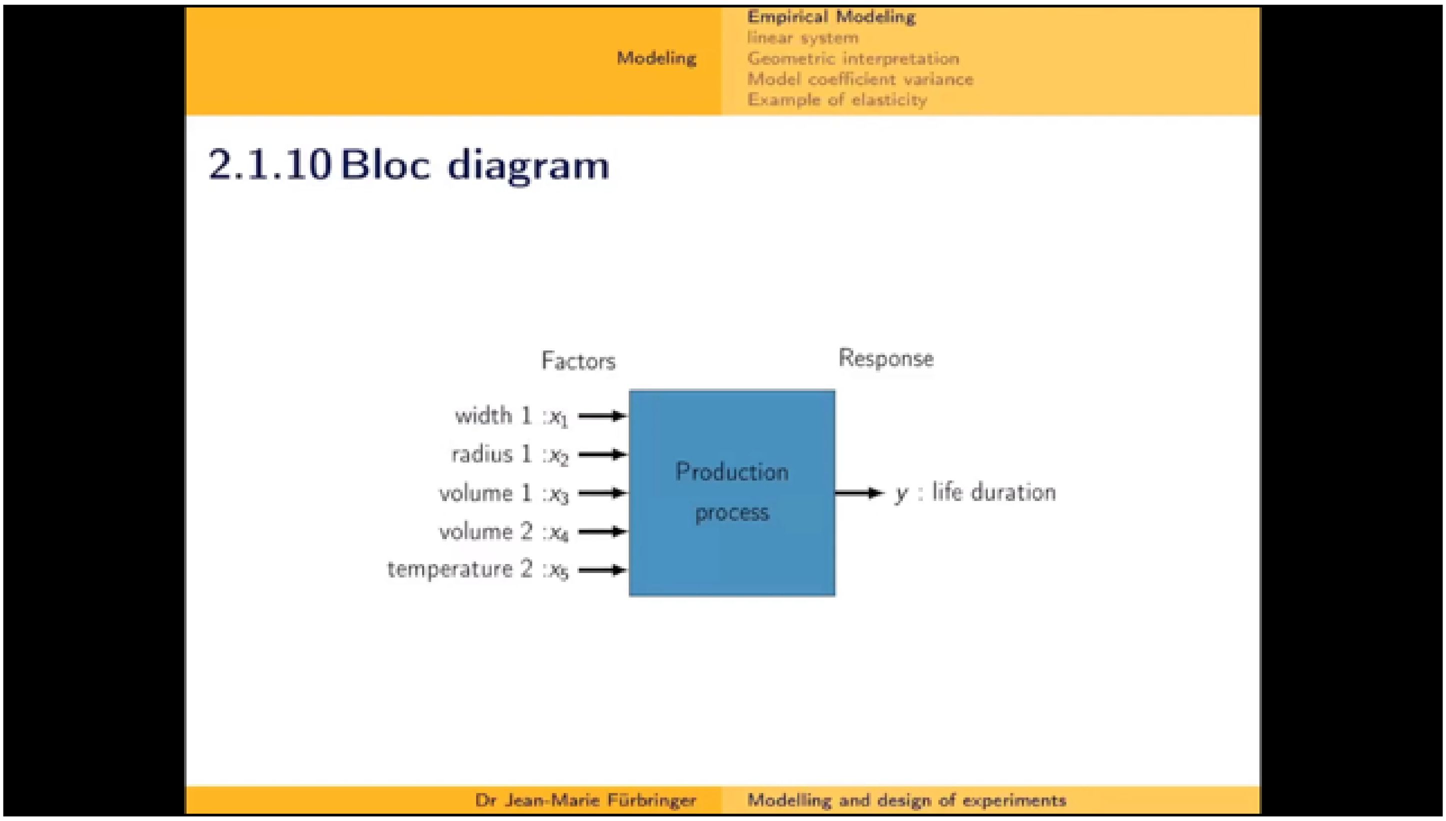

the reverse for something else but so this is the problem of the construct validity so what you get the threat is to have a model we say weak models the model is just representing what you test and can you really generalize your model for the humanity in my my example when in fact it's just a model for men weak indicators is more or less the same the same thing and weak signals and bias more or less the same the same ideas when you want to make a model for something you don't want only to model what you get in your laboratory you want that if you are testing rocks you want not to to have the real which is only for this rock in fact we want to know if you can put a nuclear waste in the place and it's okay that what you have in your laboratory is correct or is not correct but what about all the all the rock in this place no no for the case of the master project you are modeling one box but what about the other box is your model only valid for your box or is your model valid for all the similar box you have the orange box and the green box has a green box okay this is this is the problem of this weak model or what is the validity of your model and after is the what we call the external validity again are you able to generalize so you see it's the limit is not so so clear but it's is a scale and you go from very local problem you make an error in your data you give a problem in your what you say and what you build your construction is really valid outside of your laboratory so remember the slide when you are finishing making your report

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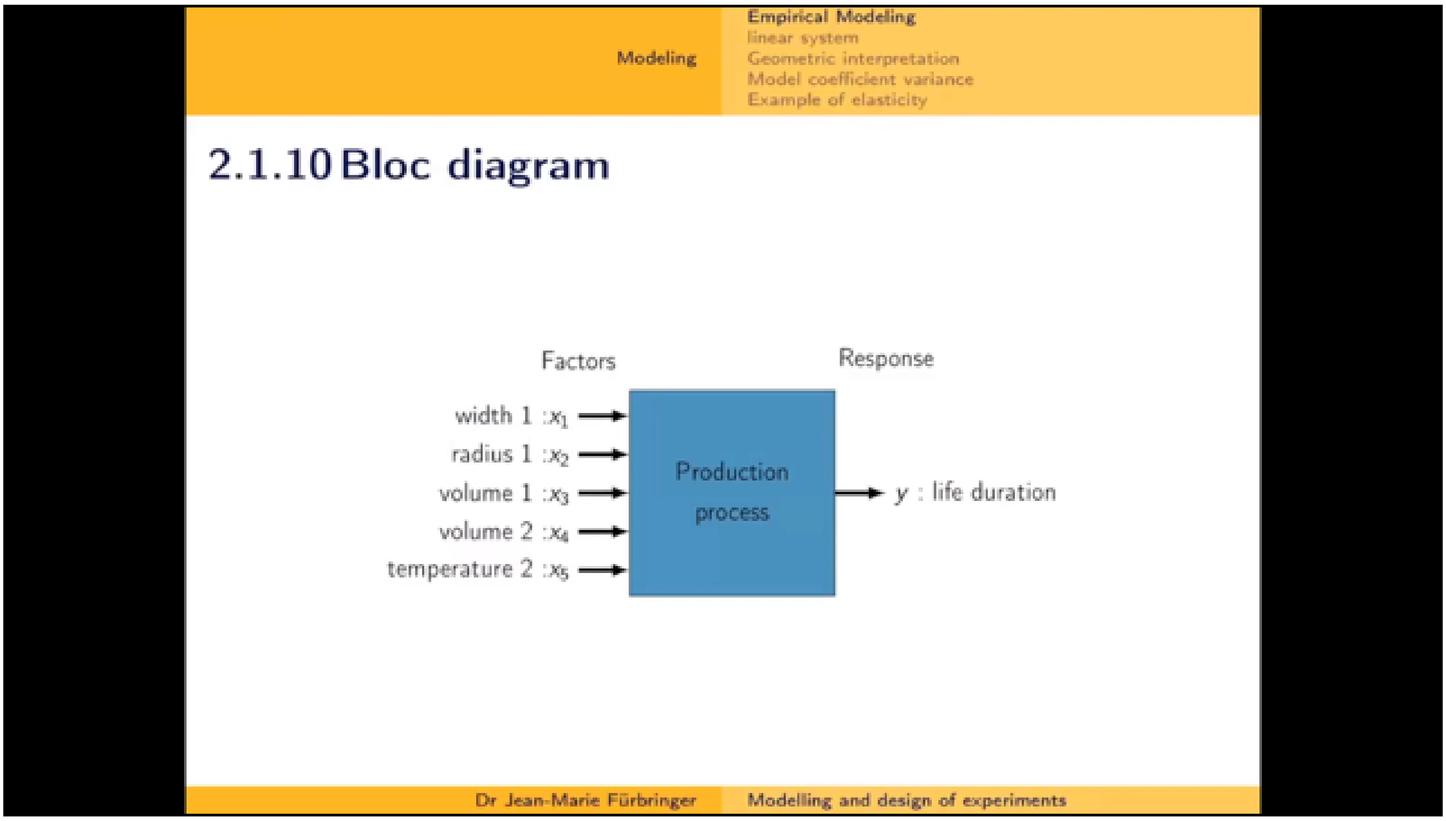

or when you are revising the work of of somebody where if you are referee who's also something you can look at it and say okay it's probably nice what i read in the article is correct but what about generalization this is my mental model of the experimental situation is a block diagram i have factors inputs usually in these experiments we talk about factors but in electronics we talk

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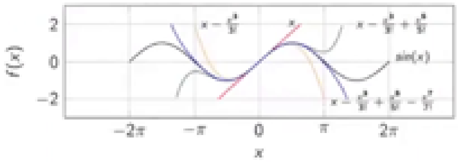
2.1.11 Taylor series

Theorem : If $U \subset \mathbb{R}^n$ and f is an application of U in $\mathbb{R}^p$ of class C^q. $\forall x_o \in U$ and $h \in U$ so that $x_o + h \in U$, we have
$f(x_o + h) = f(x_o) + df_a(h) + \frac{1}{2!} d^2 f_a(h, h) + \ldots + R_n$

Taylor polynomial :
$f(x) = a_o + a_1 x_1 + a_2 x_2 + a_{12} x_1 x_2 + a_{11} x_1^2 + a_{22} x_2^2 + \epsilon$

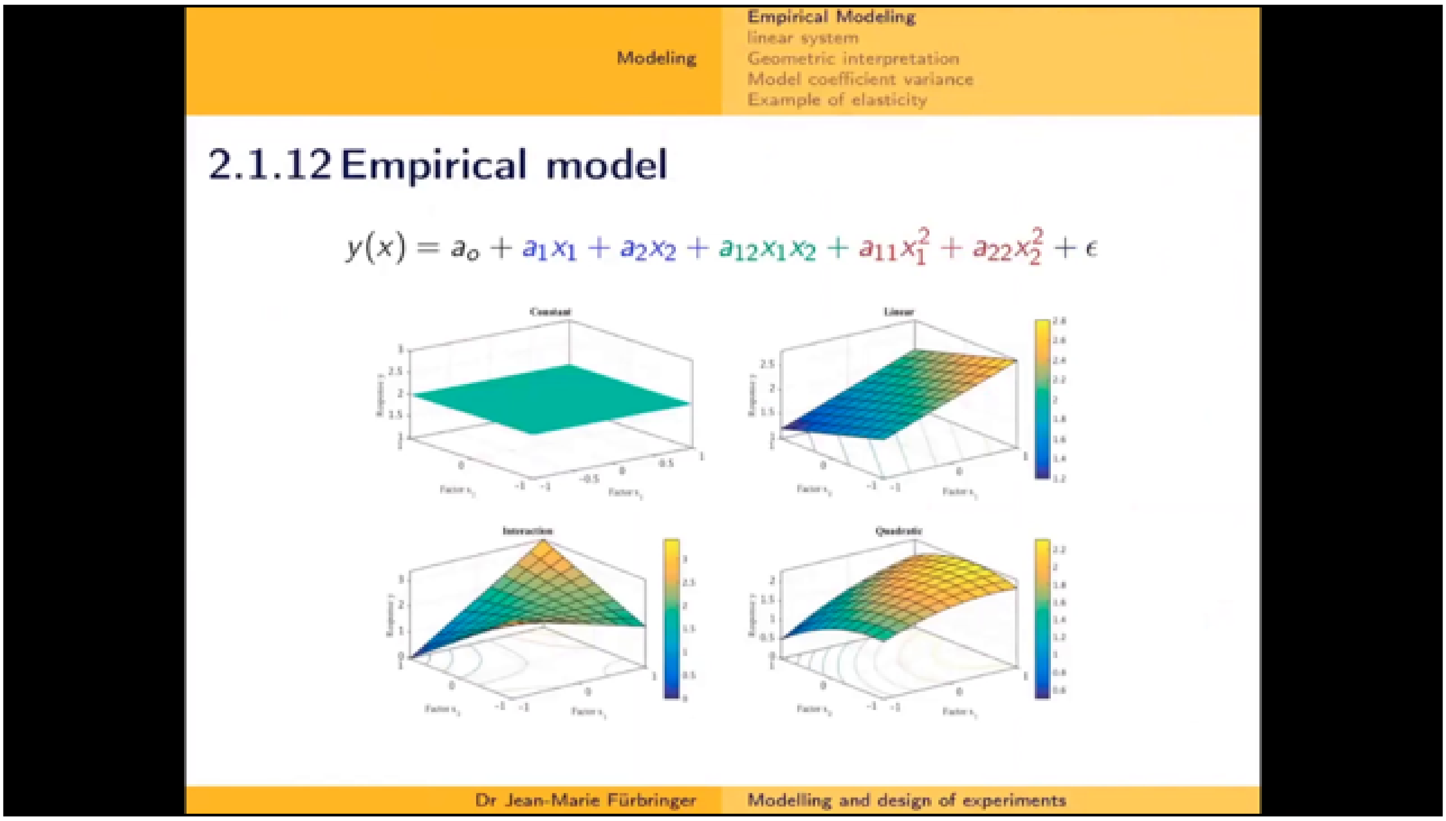


about inputs or mechanics we talk about inputs and we have output we call them responses just by convention i use the letter x for what is inputs and y for what is out you what you want but it's it's very very standard and so you have at the start a black box you have a list of factors perhaps some are real some perhaps will not have an effect the age of the captain and those adults know have no effect on on the problem and what you want is to make a model of this relation it's causation you are making the hypothesis of causation but how it's looked at and what you want to do is a mathematical model of the relation between the factors and the responses

notes

summary

31m 25s

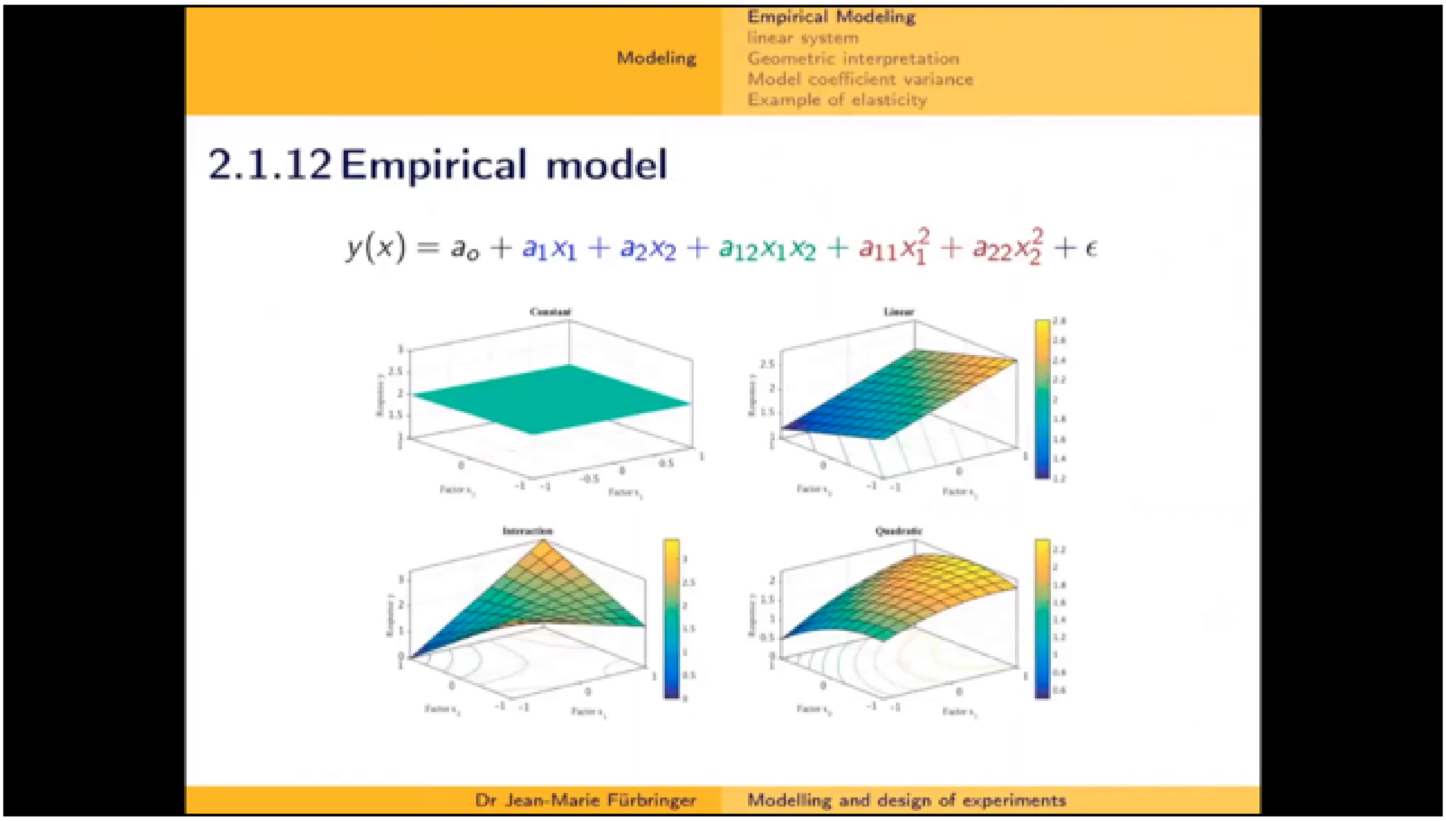


this work is a little bit more easy if we understand what we call the Taylor series so the relation between input and output could be non-linear could be very complicated could be anything that was the Taylor theorem we know that locally we are able to make a linear model of something which is eventually not linear so its work was the derivative so i will not demonstrate this theorem i consider as known the theorem say that locally if you have a function you can guess it you can approximate it close to a value it's zero is the point where you want to estimate your function and you can estimate it by the value at that place to be something you will get by experiment plus a function and you will go higher the degree of this function which is related to the derivative to first the second derivative of the function and we have more than one factor you you start having combination of the different derivative so that mean for us that we can build a Taylor polynomial around the situation and so that means that we have a first constant that i also time consider perhaps it would be zero but nevertheless i consider it and after i have a little some main effect some linear effects it's come from the derivative of the function the first derivative of the function with with each of the element and with the coefficient i like to call them a zero for the constant a 182 a 3 for the main effect of each factor a 12 a 13 a 34 etc for the interaction of the coefficient and after a 11 for the square you understand you can continue your your Taylor polynomial and here you have a small example of the approximation of the senior six which is in blue by this polynomial and you

notes

summary

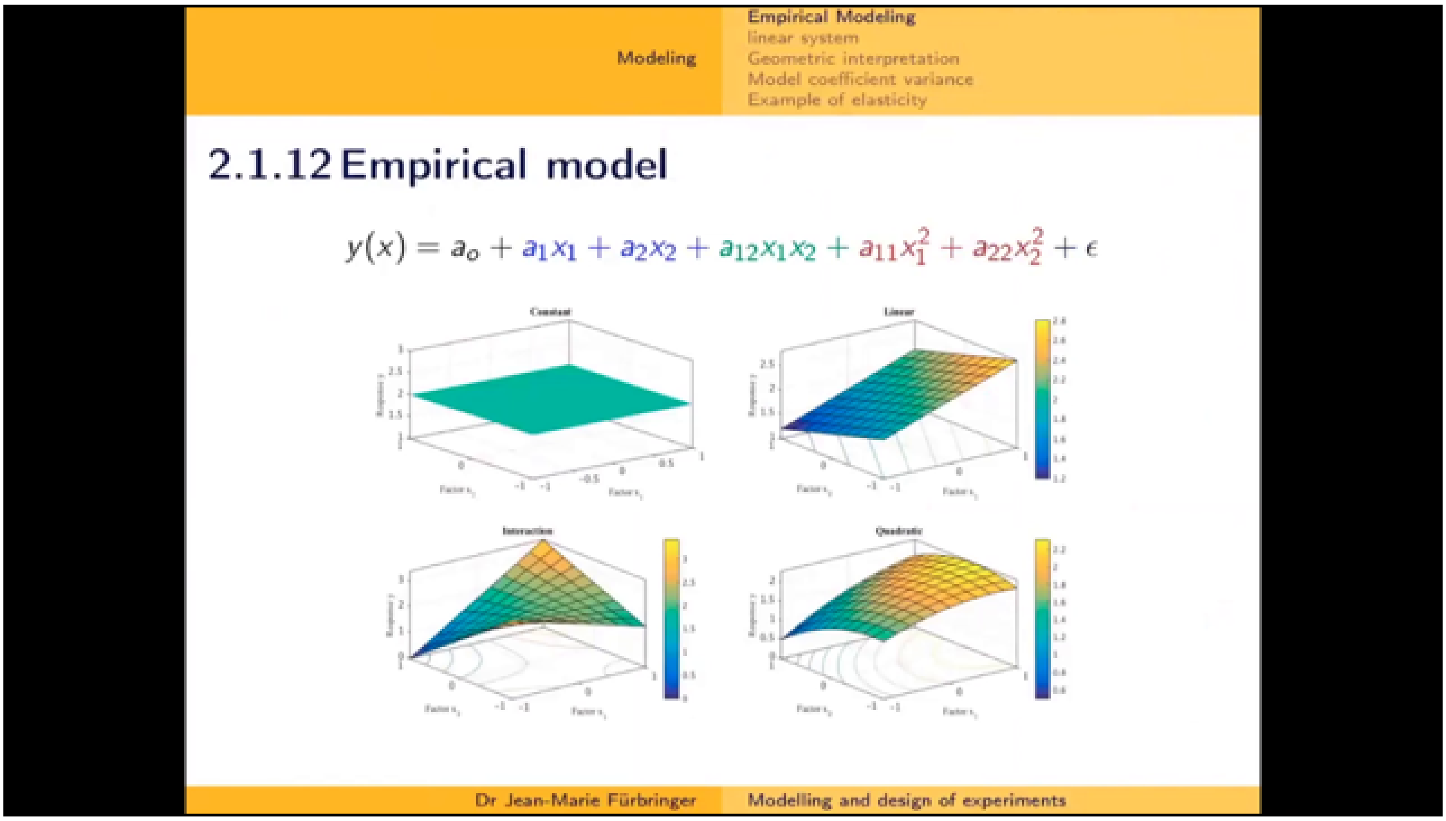
32m 28s



see that okay if you are close to zero it's work well that's when you go away from zero it's clear that this function is not able to represent a periodic behavior of of this but locally you can represent and you you can see with the different colors that more you go higher in the degree of the polynomial closer you are from your original function a 11 would be the coefficient for the second degree a 112 will be the coefficient of the cubic interaction coefficient etc and usually not usually but you you you understand that you for not because a 21 will be the same thing as a 12 because it's a commutative operation so we usually put the smaller index first and after index or like that you are not lost it's not wrong to do differently but i recommend you to do that but not you are lost my two computer are not at the same time okay so practically what it means it means that when we do not have a model it happens sometimes in a situation and you have no idea what could be the model we can build an empirical model of a situation and we start all the time the same way so as we apply this persimmon principle we would like to have the most most simple model for representing something so let's start by saying that nothing happens that in fact to make measurements it's happened with the green box when you test the green box the master student okay something happened there's a signal is changing but if you make statistical measurement eventually you see that you have a constant with different value around the constant that means that your your your your model would be would be flat the only information in this situation is that you don't know the eighth of your signal the

notes

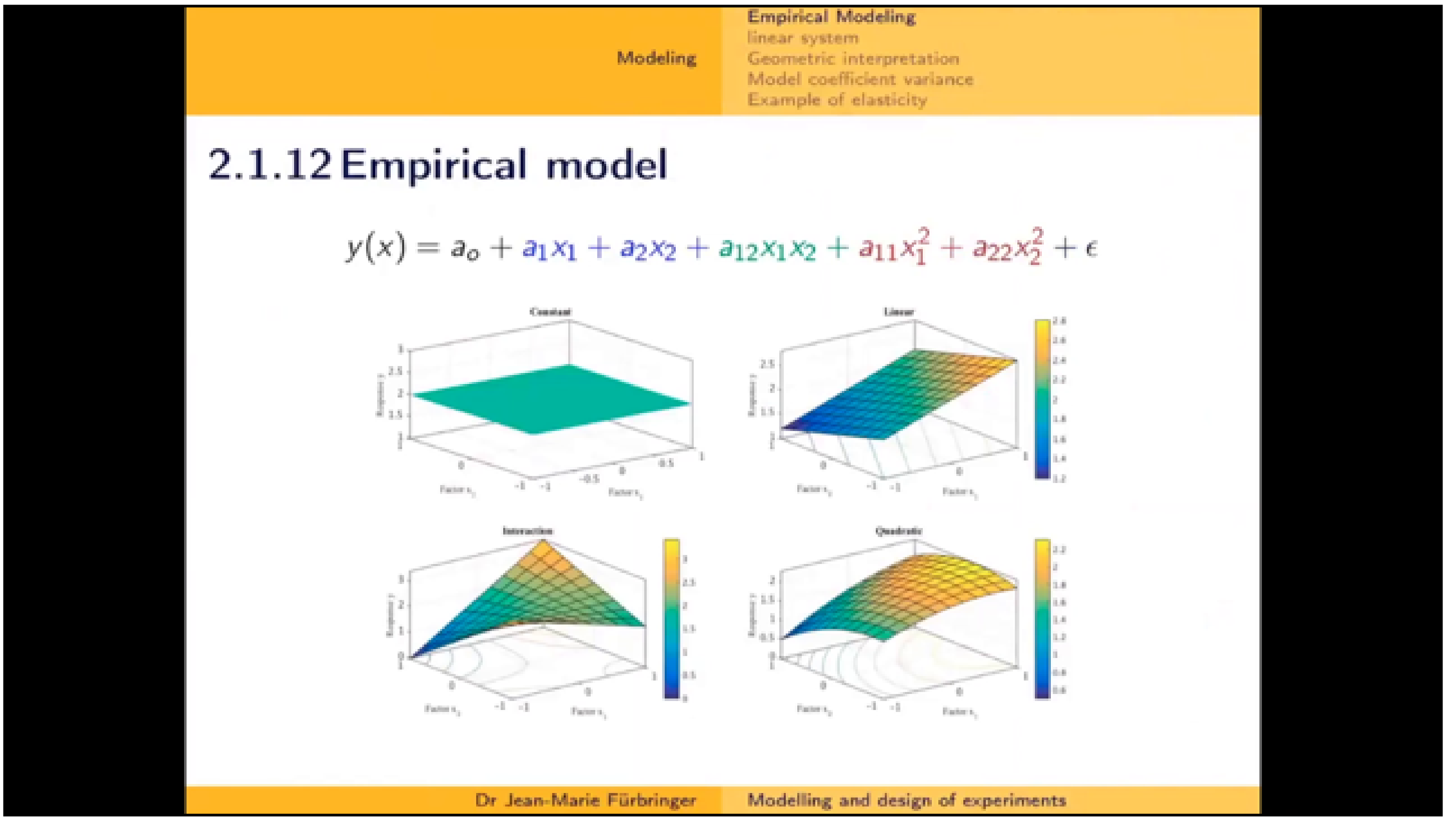
summary



average so it's an a zero so the model is just a zero and geometrically it's an hyperplane horizontal so i represented with two factors but it would be the same thing with three four five factors it doesn't change except if you cannot represent it after you have the blue part of the model you start to say okay so it's not a constant model something happened my my factors have some effect so the second step is imagining that each factor is an effect so the first one makes the eighth of your hyperplane and the second one makes a second answer because the next step will make the slope and we need one coefficient per slope it's related to the tangent of the angle but forget that what is important that you have one coefficient per factor and we call them usually the main effort and it's logical it's simple first nothing happened so don't it's happened but it's proportional to each other factor and after you start to say okay i have a slope but eventually i have some deformation in fact i have those main effect but nevertheless the the position of one factor is influencing the answer of the other factor so it's just a surface which is a little bit flat so it's an hyperplane with a deformation and it's correspond to that and even if algebraically there are no difference between they are both second degree coefficient because each one x2 or x1 square is a second degree coefficient so for mathematician it's just going to second degree empirically is not the same and for you will see that later but for discovering the model with interaction it's sufficient to make experiment at the border of your domain and you have everything you know when you go for a second degree you start having curvature in your domain when you have interaction

notes

summary



perhaps it's not correct with my ticket but in fact the geodesic are straight line but just the straight line are changing the angle depending on the value of the other parameter you see that when when you have quadratic model it's not the case the geodesic are second degree first though we can even go further nevertheless with this type of shape it's like the Lego blocks of the of the model it's really work well i will put in in model i make a matlab exercise taking the same coefficient and adding some new and you will see as this surface is is changing and you and you understand that yeah normally it's already correct with that we can do a lot of things with that we can understand what is the most important factors even with just that and we can understand where you have your maximum where you have your minimum very probably your real factor will not be a very beautiful second degree coefficient but it's already sufficient for finding what what to this is what we call the empirical modeling

notes

summary