Zurich University
of Applied Sciences

School of
Engineering
IAMP Institute of Applied
Mathematics and Physics

Models and Simulation in Business:
Understand the Past - Optimize the Present - Prepare the Future

CTI – project Complexity 4.0

Rudolf M. Füchslin

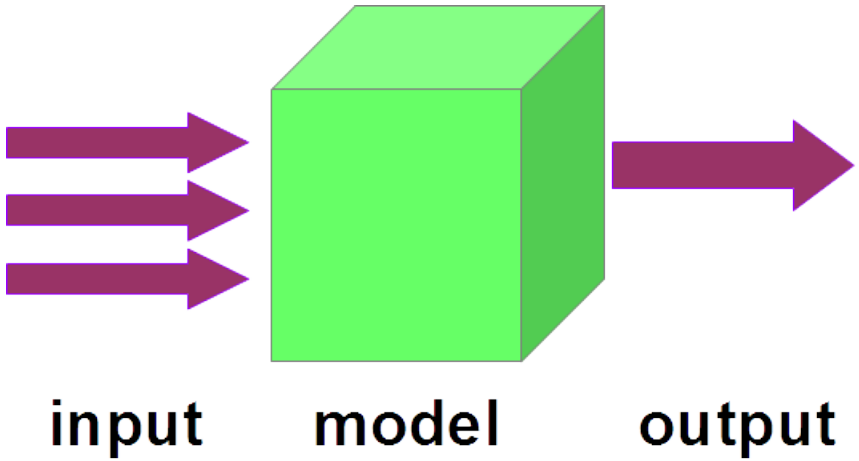
Applied Complex Systems Sciences

Why Models?

- Check your **understanding** of the past
- **Optimize** the present
- **Predict the future** if you know the present
- **Estimate the future** if you guess the present
- **Explain what we see:** Transform data into meaning
- **Produce data and train modern controllers** (e.g. deep neural nets)
- The non – ideal world: Dealing with **fluctuations**
- Find your **weaknesses,** identify your **strengths**

What is a Model?

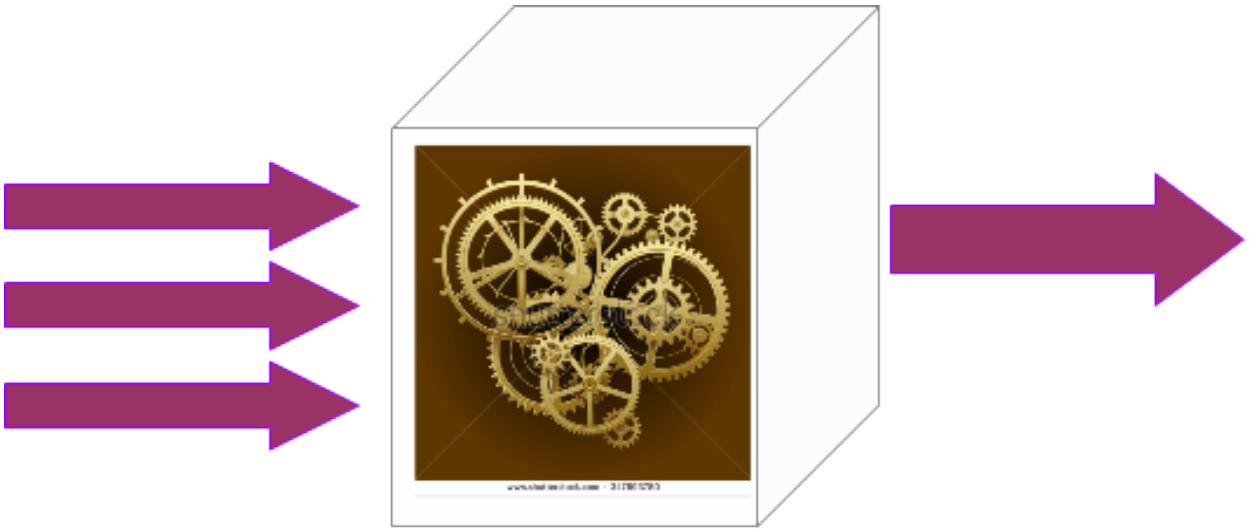
- A model maps input onto output



- Example
  - Input: prizes of basic resources, processes and markets
  - Output: revenues

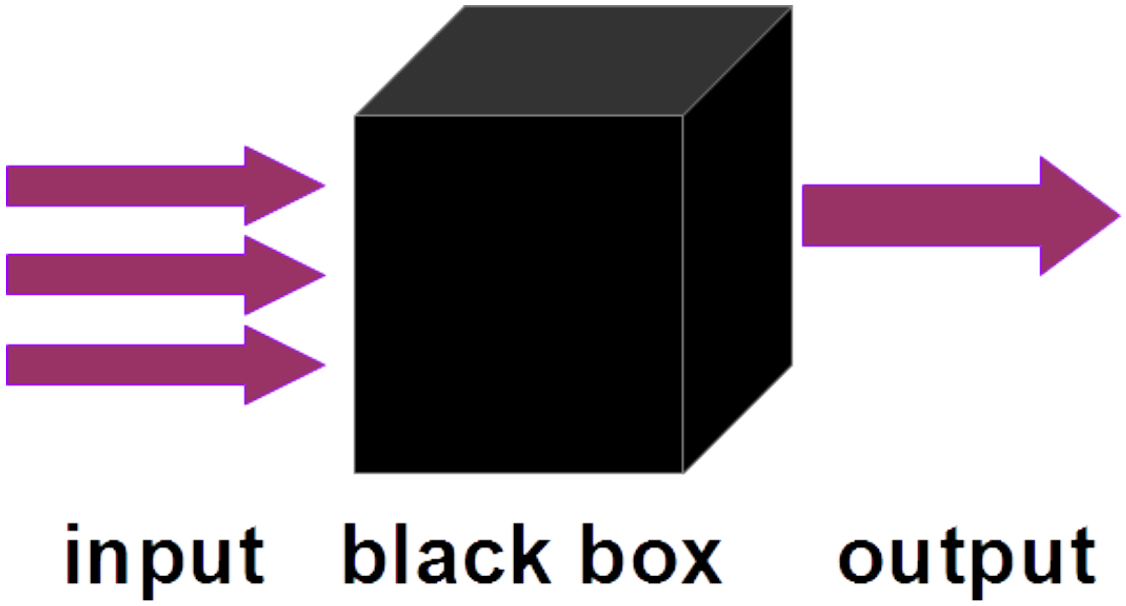
What is a Simulation?

- You have a precise idea of how the input is transformed into the output



Black Box Models

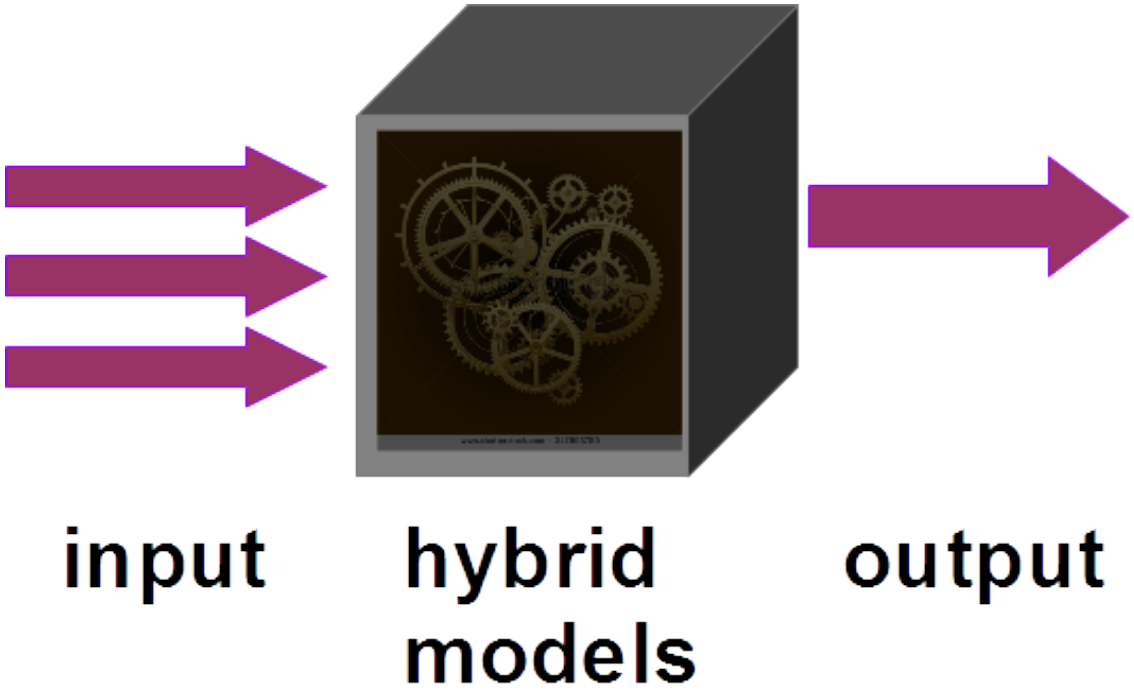
- Sometimes, you don't know what is going on, but you may have data (input – output pairs)



Hybrid Models

Zurich University of Applied Sciences
School of Engineering
IAMP Institute of Applied Mathematics and Physics

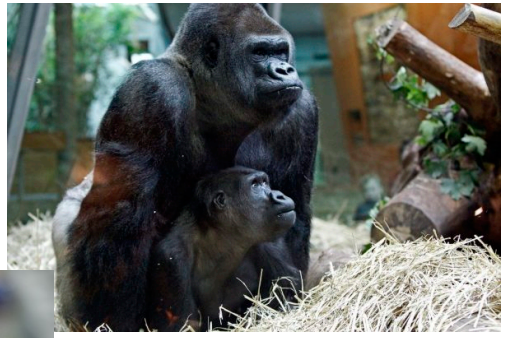
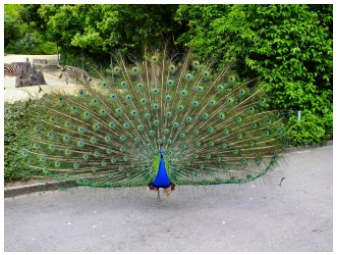
- Usually, it is something in between perfect knowledge and complete ignorance



How Do We Do It?

- There is a zoo of methods for simulations, black box and hybrid models. There are pets and beasts.



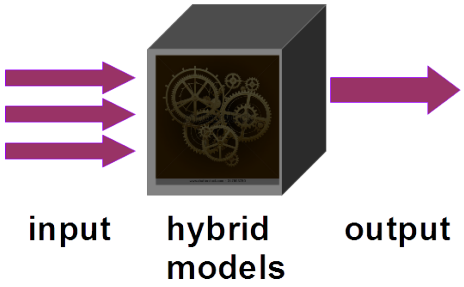



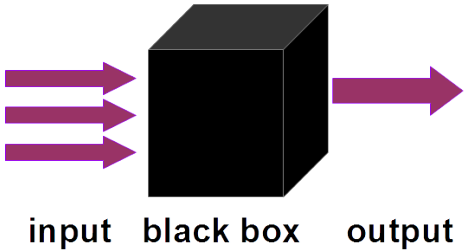


What is a Model Good For?

Zurich University of Applied Sciences
School of Engineering
IAMP Institute of Applied Mathematics and Physics

- Assume you have a model





- **What can we do with it?**

What is a Model Good For?

Zurich University
of Applied Sciences
School of Engineering
IAMP Institute of Applied Mathematics and Physics

- Understand the past
- Optimize the present
- Predict the future
- Quantify future scenario
- Analyze resilience

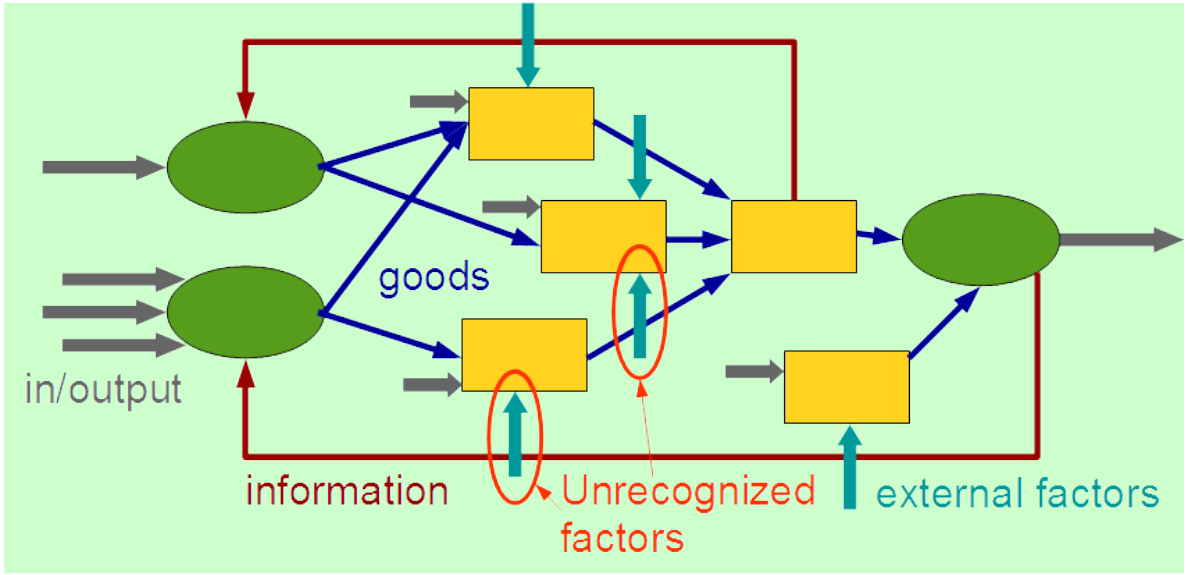
Understand the Past

Zurich University of Applied Sciences
School of Engineering
IAMP Institute of Applied Mathematics and Physics

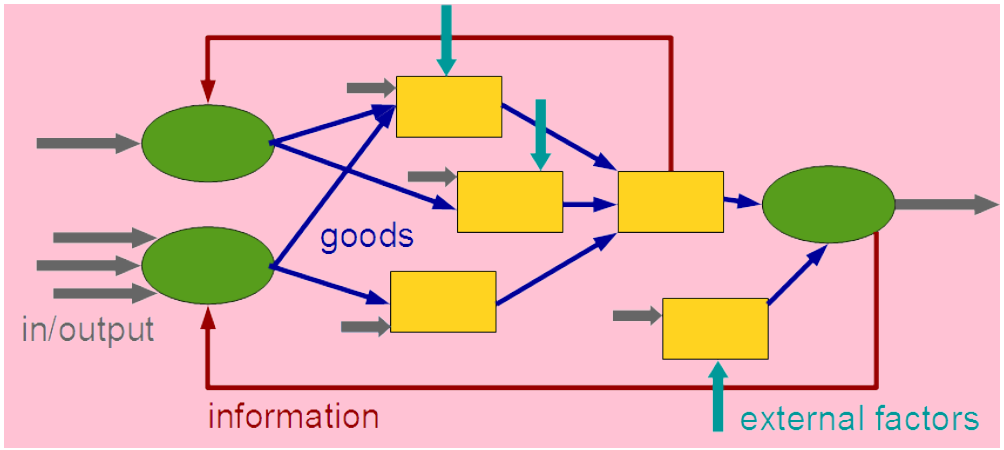
- Model reflects your understanding of processes, inputs and external factors
- Simulation reproduces past input – output pairs correctly ➔ **Your understanding of the system is probably highly adequate**
- Simulation fails ➔ **Can indicate incomplete knowledge**
- ➔ **Action: Sharpening of ideas about system and environment**

Example: Identify External Factors

Zurich University of Applied Sciences
School of Engineering
IAMP Institute of Applied Mathematics and Physics



Initial model, does not reproduce past



New influence factors are identified, model reproduces past input-output pairs

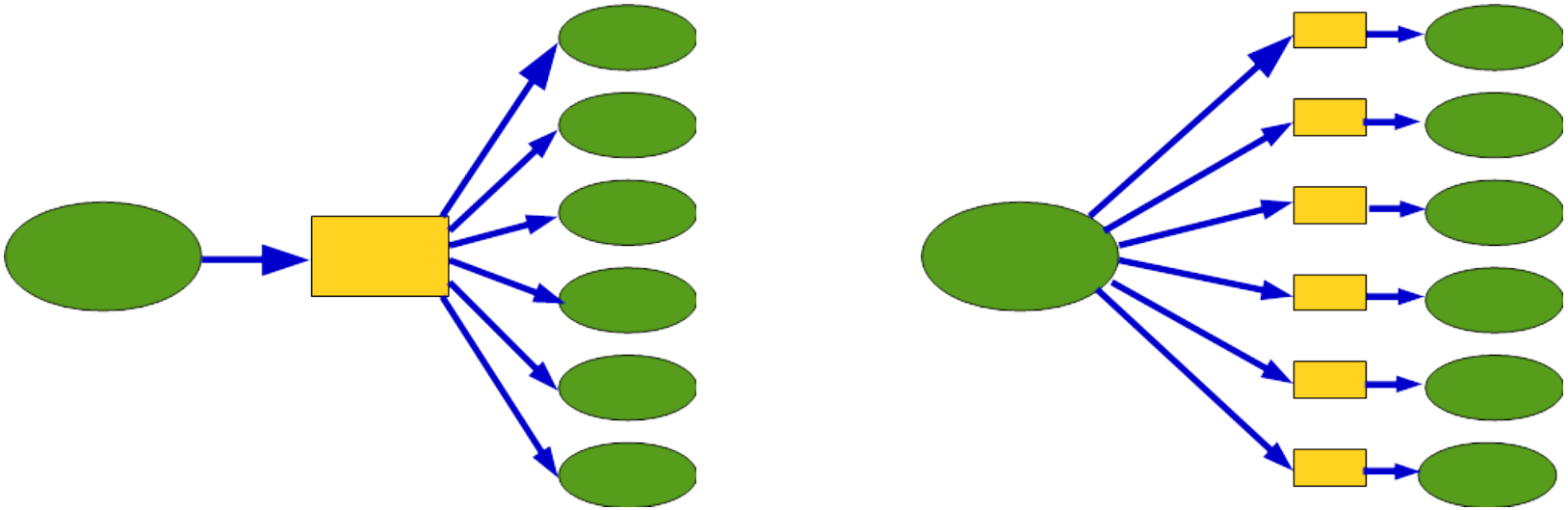
Optimize the Present

Zurich University of Applied Sciences
School of Engineering
IAMP Institute of Applied Mathematics and Physics

- Every model is **validated** with past data
- One may **study variants** of the model and optimize the system
- Important: Optimization requires a **fitness function**!
- There are different types of fitness functions; **the user can experiment with models and objectives**

Example: Central or Local?

Zurich University of Applied Sciences
School of Engineering
IAMP Institute of Applied Mathematics and Physics



- Central or local production?
- How to compare costs vs. resilience?

Prepare for the Future

Zurich University
of Applied Sciences
School of Engineering
IAMP Institute of Applied Mathematics and Physics

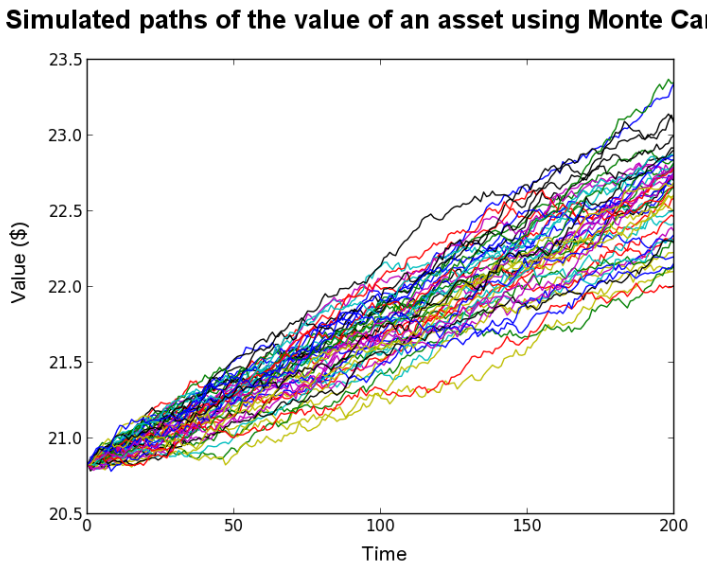
- Assumption: A validated model
- Given the input and the external factors, we can predict the outcome
- ➔ **Test of scenarios**

Example: Best/Worst Case

Zurich University of Applied Sciences
School of Engineering
IAMP Institute of Applied Mathematics and Physics

- Input/output and external factors in the future may not be known
- Reasonable parameter ranges may be known
- ➔ model – based sampling in the parameter space
- **➔ identify best, worst case and most likely case**

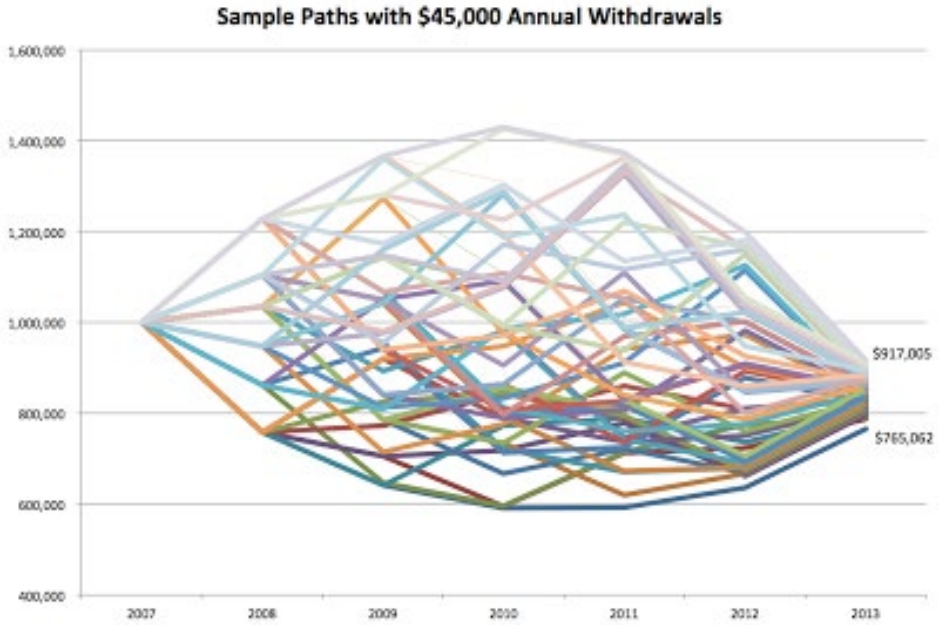
Example: Best/Worst Case



Strategy:

- ***Prepare for the worst,***
- ***expect the most likely,***
- ***hope for the best!***

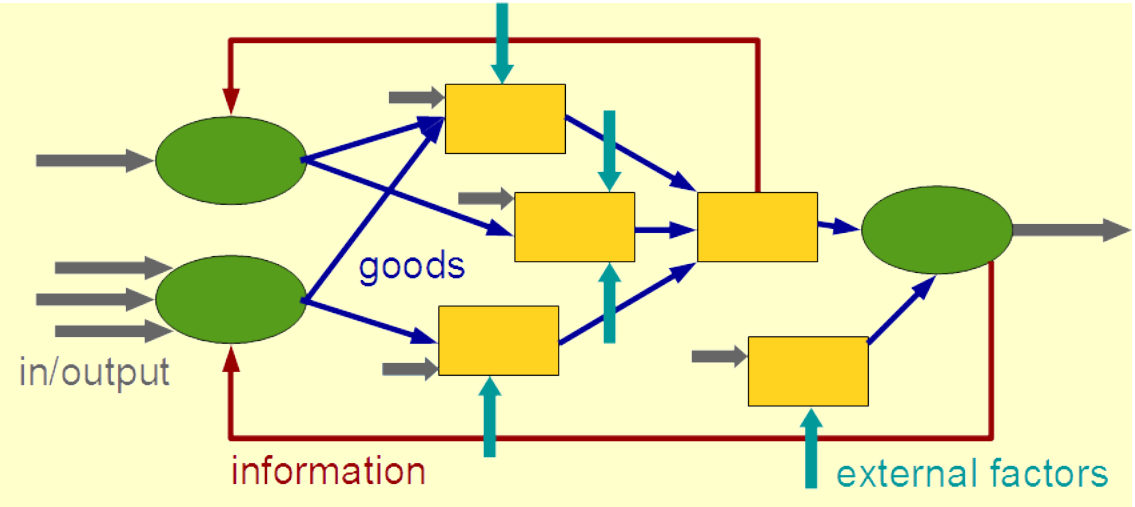
(Gen. S. McChrystal)



The Real World: Fluctuations

Zurich University of Applied Sciences
School of Engineering
IAMP Institute of Applied Mathematics and Physics

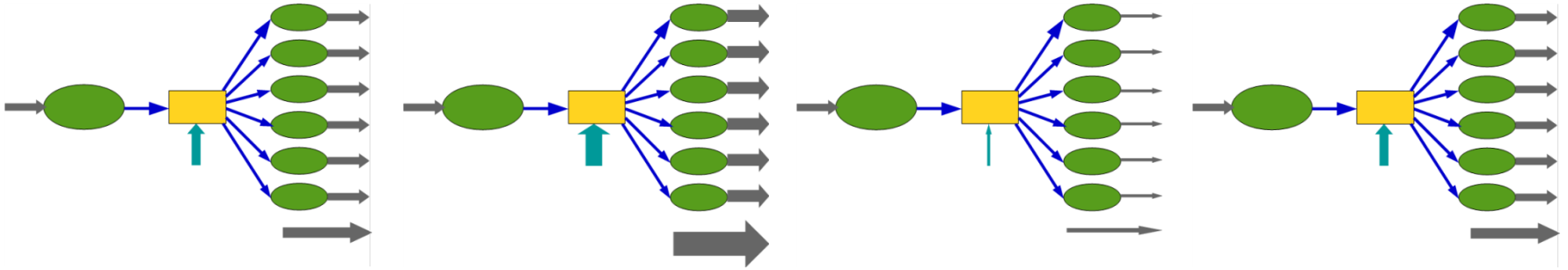
- The external factors / inputs may be varying over time
- ➔ The model can estimate the **variations in output**, assuming fluctuations in input / external factors



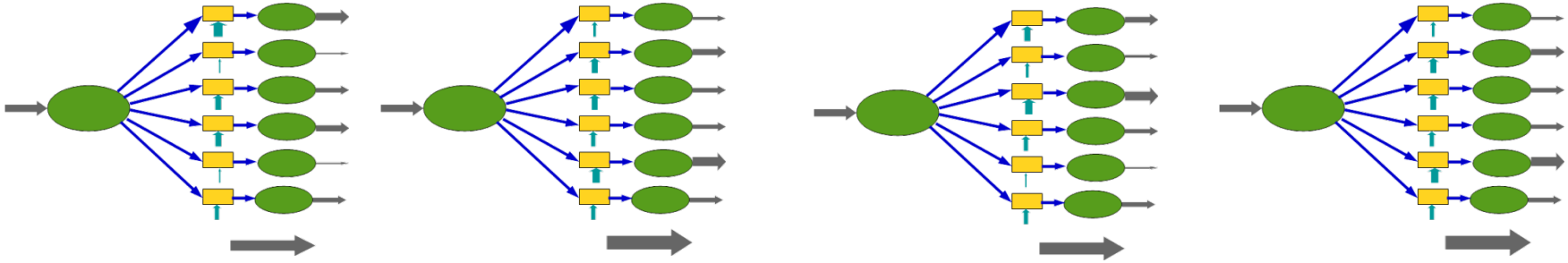
Example: Robustness

- What scenario is preferable?

centralized production, large fluctuation of total output



time



local production, small fluctuation of total output

Identify Weaknesses and Strength

Zurich University
of Applied Sciences
School of Engineering
IAMP Institute of Applied Mathematics and Physics

- Vary external factors of individual components
- ➔ Identify the most vulnerable part of the system
- ➔ Identify the resilient parts of the system

What Information Do We Need?

- What question do you want to answer:
  - Understand the past: Is there an appropriate understanding of external factors, processes and I/O – relations? Is data available?
  - Optimize the present: How to optimize the system? What is the “fitness function”?
  - Prepare the future: Scenario analysis (best/worst case)
  - Is the system resilient?
- What do you know?
- What do you guess? How do you guess?

Happy to Answer Questions

Zurich University of Applied Sciences

School of Engineering

IAMP Institute of Applied Mathematics and Physics

Prof. Dr. Rudolf M. Füchslin

Institute for Applied Mathematics and Physics
Head of Group for Applied Complex Systems Sciences
Technikumstr. 9
CH-8401 Winterthur, Switzerland
www.zhaw.ch/iamp

European Centre for Living Technology
Co - director
S.Marco 2940
30124 Venice, Italy
http://www.ecltech.org/

Office: +41(0)58 934 75 92
+39 0 41 234 75 94
Mobile: +41(0)79 232 74 36

Skype : rudolf.marcel.fuechslin

rudolf.fuechslin@zhaw.ch

Machine Learning

Zurich University of Applied Sciences

School of Engineering

IAMP Institute of Applied Mathematics and Physics

Dr. Thilo Stadelmann

Institute of Applied Information Technology
Deputy head of Information Engineering group
Technikumstr. 9
CH-8401 Winterthur, Switzerland
www.zhaw.ch/init

ZHAW Datalab
Head of the board
www.zhaw.ch/datalab

Office: +41(0)58 934 72 08
Mobile: +41(0)79 934 02 80

Skype : thilo_at_skype

thilo.stadelmann@zhaw.ch

Discrete Event / Agent-based Simulation
Business und Service Process Modelling

Zurich University of Applied Sciences

School of Engineering

IAMP Institute of Applied Mathematics and Physics

Dr. Jürg Meierhofer

Office: +41 (0) 58 934 40 52
juerg.meierhofer@zhaw.ch

Patrick Kehrli

Office: +41 (0) 58 934 64 04
patrick.kehrli@zhaw.ch

Institute of Data Analysis and Process Design (IDP)
ZHAW Plattform Industrie 4.0
Rosenstrasse 3
CH-8401 Winterthur, Switzerland
www.zhaw.ch/idp

Simulation & Optimization

Zurich University of Applied Sciences

School of Engineering

IAMP Institute of Applied Mathematics and Physics

Dr. Lukas Hollenstein

Institute of Applied Simulation
Center for Simulation & Optimization
Einsiedlerstrasse 31a
CH-8820 Wädenswil, Switzerland

www.zhaw.ch/ias
www.zhaw.ch/ias/simopt

Office: +41 (0)58 934 54 02
Mobile: +41 (0)78 870 66 22
Skype: lukasho

lukas.hollenstein@zhaw.ch