MSU MU SIGMA UNIVERSITY

THURSDAY LEARNING HOUR

Mu Sigma

Prescriptive Intelligence

Intelligence Driven Decision Making

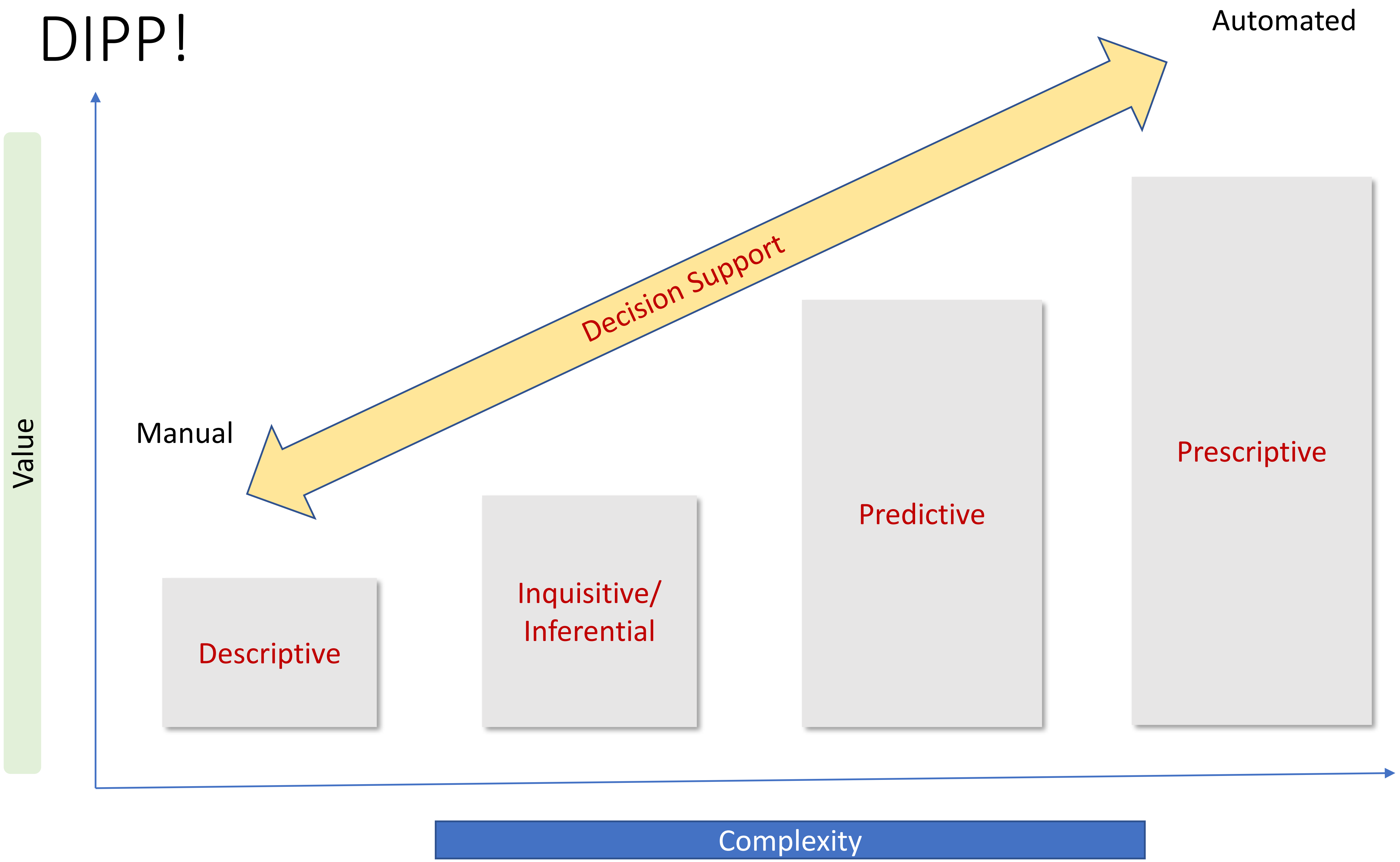
Speaker : Prabakaran Chandran

Date: 28th April 2022 Location: Zoom Time: 6:00 PM – 7:00 PM IST

Agenda

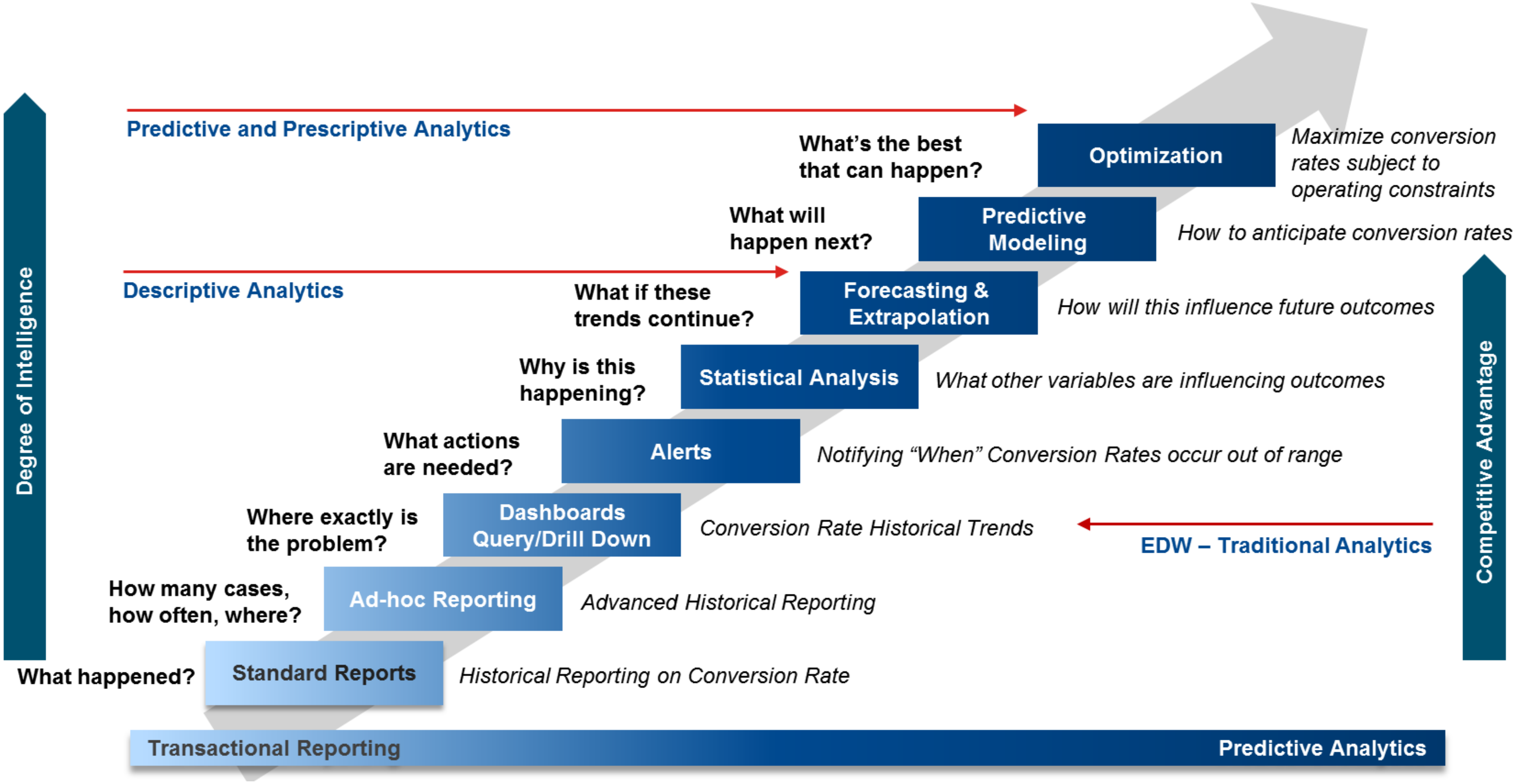
- DIPP Stack of Analytics
- Introduction to Prescriptive Intelligence
- Components of Prescriptive Intelligence
- Simulation - Methods to Replicate your System
- Optimization for better Decisions
- Different optimization methodologies
- Reinforcement Learning for Decision Support
- Unstructured Data and Prescriptive Intelligence
- Industries and Prescriptive Intelligence

DIPP!



Automated
Decision Support
Manual
Value
Descriptive
Inquisitive/
Inferential
Predictive
Prescriptive
Complexity

DIPP - Landscape



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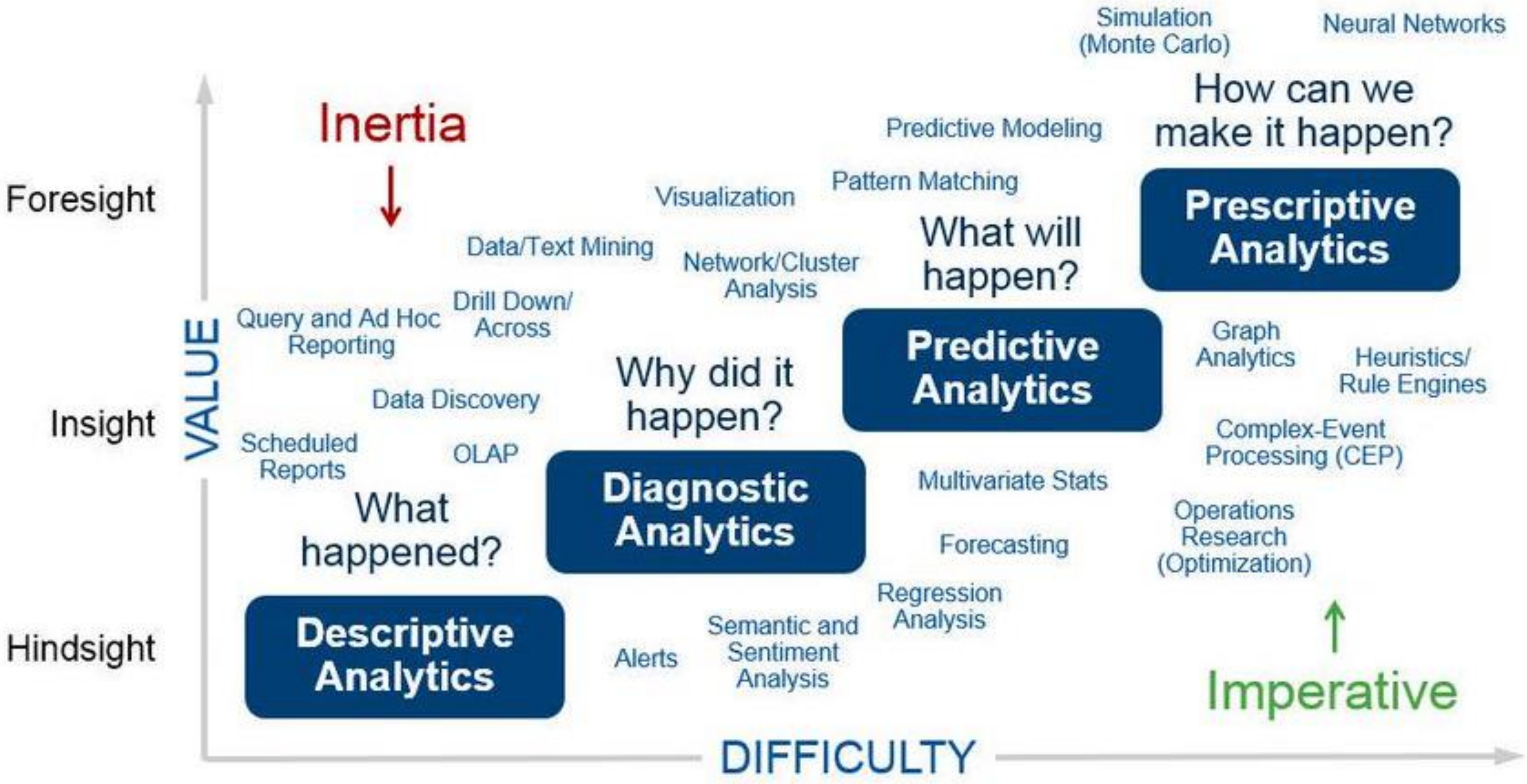
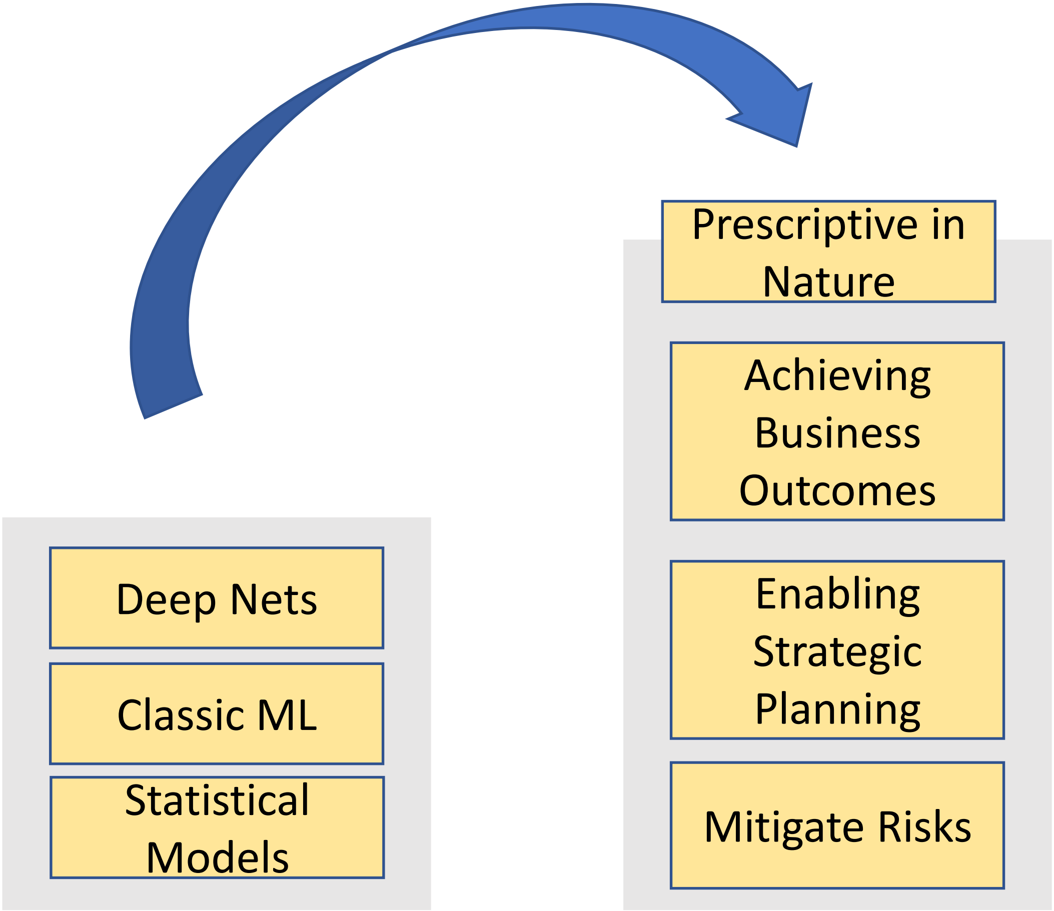


Simulation (Monte Carlo)
Neural Networks
How can we make it happen?
Inertia
Predictive Modeling
Foresight
Pattern Matching
Visualization
Prescriptive Analytics
What will happen?
Data/Text Mining
Network/Cluster Analysis
Drill Down/ Across
Query and Ad Hoc Reporting
Predictive Analytics
Graph Analytics
Heuristics/ Rule Engines
VALUE
Why did it happen?
Data Discovery
Insight
Complex-Event Processing (CEP)
Scheduled Reports
OLAP
Multivariate Stats
Diagnostic Analytics
What happened?
Operations Research (Optimization)
Forecasting
Regression Analysis
Descriptive Analytics
Semantic and Sentiment Analysis
Hindsight
Alerts
Imperative
DIFFICULTY

What is Prescriptive Analytics / Intelligence ?



- **"final frontier of analytic capabilities"**
- **suggests decision options to take advantage of the results of descriptive and predictive analytics.**

These Questions Don't want just the Predictions

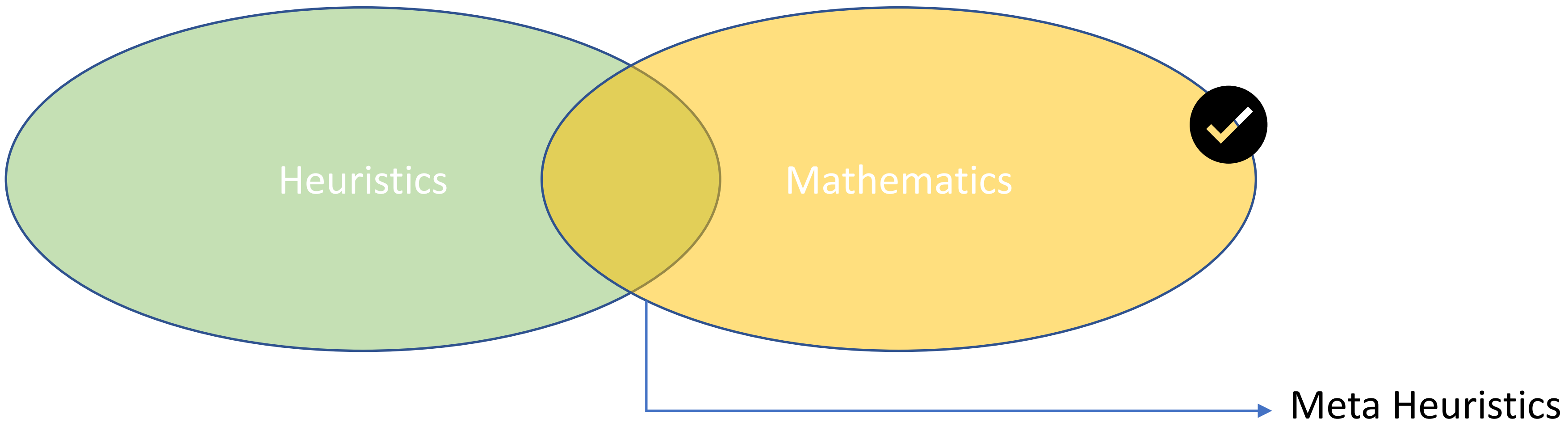
- What's the next promotion that I can offer to this customer segment?
- How do we optimize production on these widgets?
- What is the best course of action to optimize our customer journey?
- Which product is the best fit for our customers?

Approaches to build Prescriptive Analytics

The prescriptive analytics market consists of two categories of algorithms:
--- heuristics (rules) and exact / Mathematical.

- Heuristic algorithms do not guarantee the best answer. If designed well, they can offer a short-cut approach to finding good answers in a reasonable amount of time.

- Exact algorithms guarantee the best answer. However, for difficult problems, the time to solve for the best answer can increase exponentially compared to the size of the problem.



How to select the best approach here

•**TYPE**: Some problems are naturally better for heuristics, while others are better for optimization. There are lists below citing examples of each.

•**COMPLEXITY**: How difficult is the problem? There are well-known problems — e.g., traveling salesman — that can be difficult to find the best answer using optimization. In some cases, finding a good solution quickly using rules might make sense compared with optimization.

•**PERFORMANCE**: How long are you willing to wait for an answer each time you solve the problem? If an answer must be found as soon as possible, a heuristic might be a better choice. If time is not a major concern, optimization might be a better choice.

•**FREQUENCY**: How often must the problem be solved? If a new decision must be made frequently, maybe hundreds, even thousands, of times each day, then heuristics is likely to be a better choice over optimization.

Business Heuristics based Prescriptive Analytics

- Heuristics are a set of problem-dependent rules.
- They are best used when the problem can be narrowly defined and operational in nature, rather than tactical or strategic.
- they can be a good choice when the same decisions must be made by hundreds, thousands, even millions of times per day.
- Less Number of possible events/actions

•**RAW MATERIAL PURCHASES**: e.g., purchase the cheapest source of raw material first regardless of quality
•**CAPACITY ALLOCATION**: e.g., assign capacity to line 1 first, then line 2 second, and so on, regardless of operating efficiency or costs
•**MARKETING**: e.g., offer customers promotional opportunities based on a website search or prior purchase
•**DEMAND FULFILLMENT**: e.g., Tier 1 customers must always have their service level met at the expense of lower tier customers

- Excel based What-if Scenarios for the quicker Decision Automation
- Can be easier to learn, configure, and implement

•Limited benefits for holistic decision-making across functions (e.g., Integrated Business Planning) with a low ROI
•"Good enough" answers are not guaranteed optimal (and often no mathematical proof)
•Won't analyze every possible scenario

Optimization based Prescriptive Analytics

- Optimization is a combination of mathematical modeling and exact algorithms used to find the optimal answer. A problem is defined by writing math equations using a model building platform. Once the model is created, it is sent to a highly specialized algorithm used to solve the problem.

DECISIONS TO BE SOLVED FOR

- How much raw material to purchase?
- How many hours to run each line?
- How much product to sell to certain markets?

DATA TO BE INPUT

- How much does each ton of raw material cost?
- What does it cost to run each line?
- What is the recipe for SKU #123 at Plant A?
- At what price is the product sold in each market?

BUSINESS REALITIES/RESTRICTIONS THAT MUST BE ADHERED TO

- How much is raw material available to purchase?
- How many hours does each line have available?
- What is the maximum amount of demand for each market?

Typical Optimization Problem with an Objective

Optimization based Prescriptive Analytics

- Optimization is a combination of mathematical modeling and exact algorithms used to find the optimal answer. A problem is defined by writing math equations using a model building platform. Once the model is created, it is sent to a highly specialized algorithm used to solve the problem.

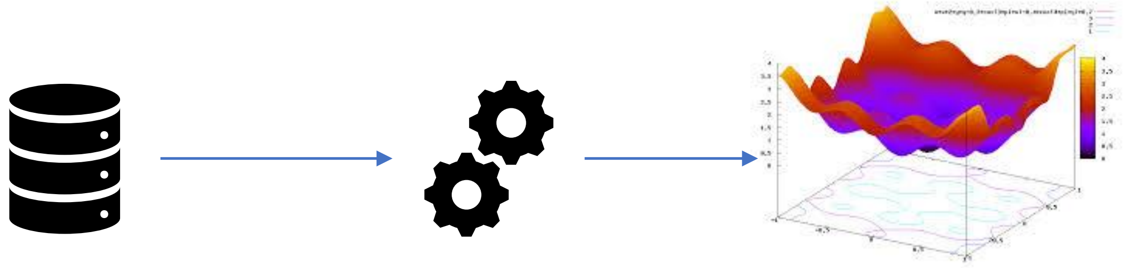
Optimization is used to solve numerous problems that are generally too complex for a heuristics-based approach.

Historically, problems solved using optimization were for a specific business function
•**TRANSPORTATION**: shipping goods from supply to demand points at a minimal cost
•**EQUIPMENT REPLACEMENT**: determining the optimum point in time to replace equipment
•**ASSIGNMENT PROBLEMS**: assigning staff to equipment
•**GASOLINE BLENDING**: for aviation fuels

Typical Optimization Problem with an Objective

What is Optimization?:

- The selection of a best element (regarding some criterion) from some set of available alternatives
- In the simplest case, an optimization problem consists of maximizing or minimizing a real function by systematically choosing input values from within an allowed set and computing the value of the function.



Data

Statistical / ML model / Mathematical Model

Function which explains the scenario

This Function is our Objective Function

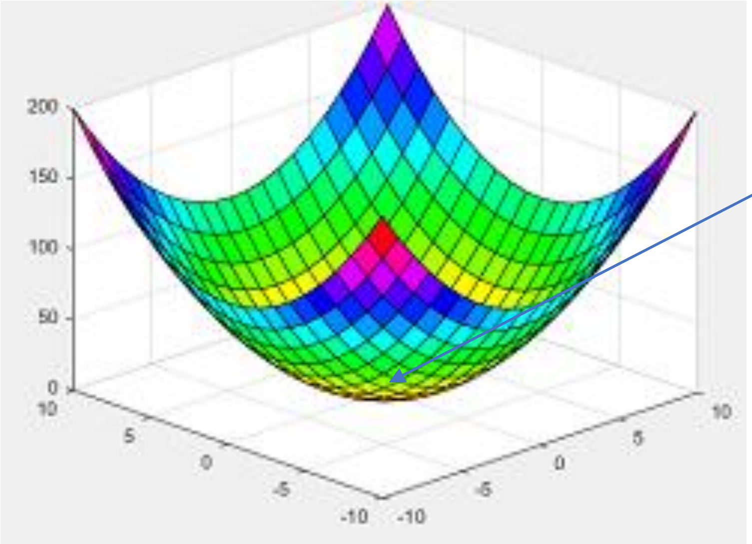
Our Objective : To find the input value which give us the minimum / maximum point of the function

Process of Reaching maxima or minima of the function is called optimization.
Sometimes , the process might be subjected to constraints.

Major Types of Optimization: Convex Optimization Vs Non-Convex Optimization:

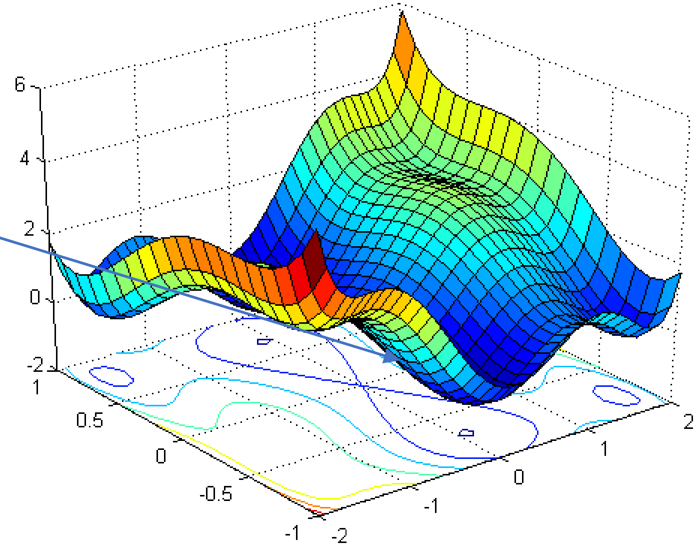
- A *convex optimisation problem* is a problem where all of the constraints are convex functions, and the objective is a convex function if minimising, or a concave function if maximising. A convex function can be described as a smooth surface with a single global minimum.

- In most of the machine learning problems we come across loss surfaces which are non-convex in nature. Hence, they will have multiple local minimum. Which is called as Non-Convex optimization



Single Optimum point

Multiple Optima includes Global and Local optima



Convex Function

Non-Convex Function

Constrained and Unconstrained Optimization

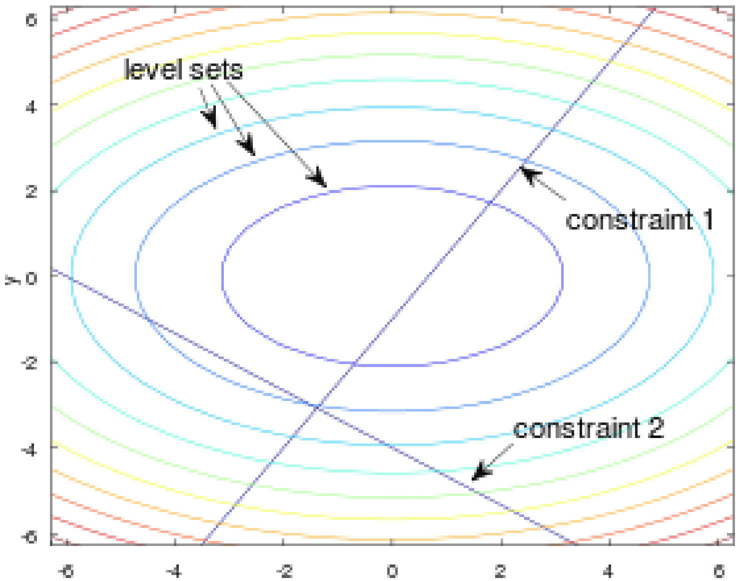
Constrained Optimization includes some conditions/limitations on the solutions

For Example: A company wants to maximize the sales , whereas they have a condition on price limit.

=> Sales = 1000-10price + 45.6units+26.5 marketing-0.25Competetor

1. Objective : max Sales
2. subjects to price > 10$ and marketing < 5000$

If we don't have any of the constraints --→ Un Constrained Optimization



Constrained Optimization

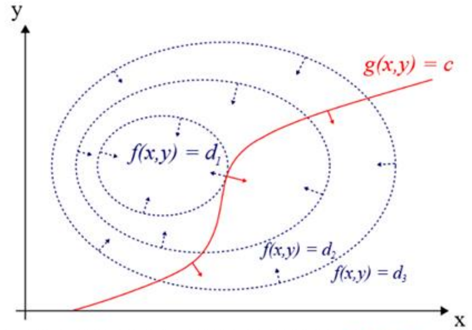


Figure 1: The red curve shows the constraint $g(x, y) = c$. The blue curves are contours of $f(x, y)$. The point where the red constraint tangentially touches a blue contour is the maximum of $f(x, y)$ along the constraint, since $d_1 > d_2$.

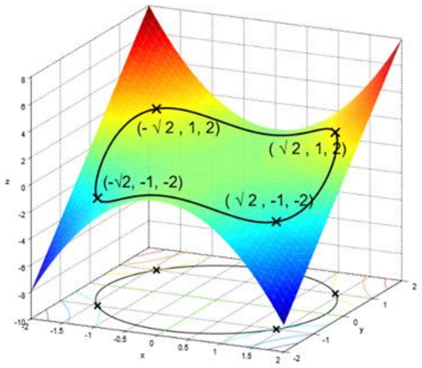
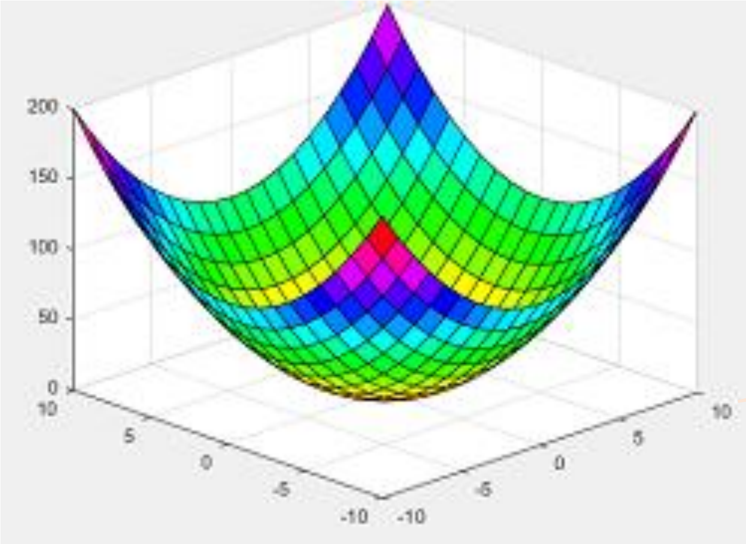


Figure 2. Illustration of the constrained optimization problem

Something is missing !



Convex Function

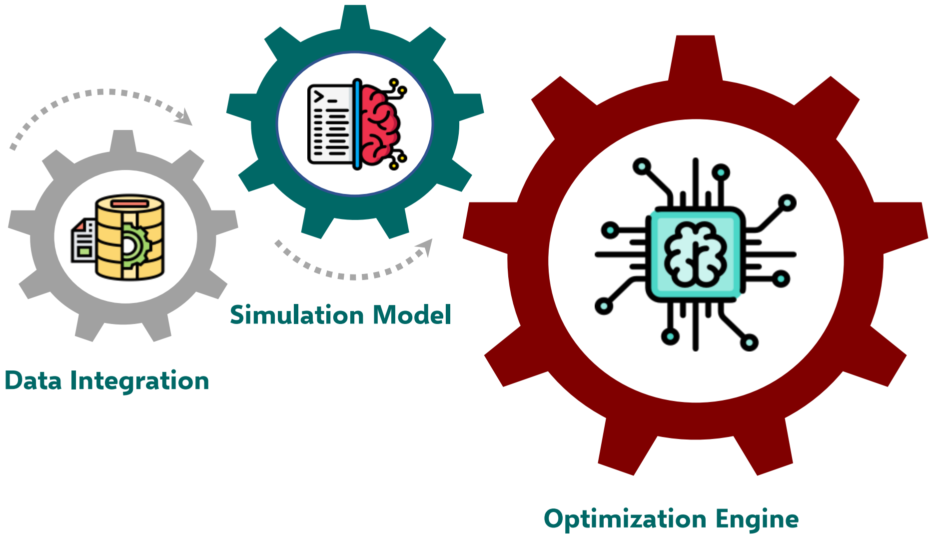
Optimization always need an Objective Function -- > Nothing but an Equation ! → What is We don't have that Equations directly ? More complex Real Time Systems cannot be just Represented in terms Equations

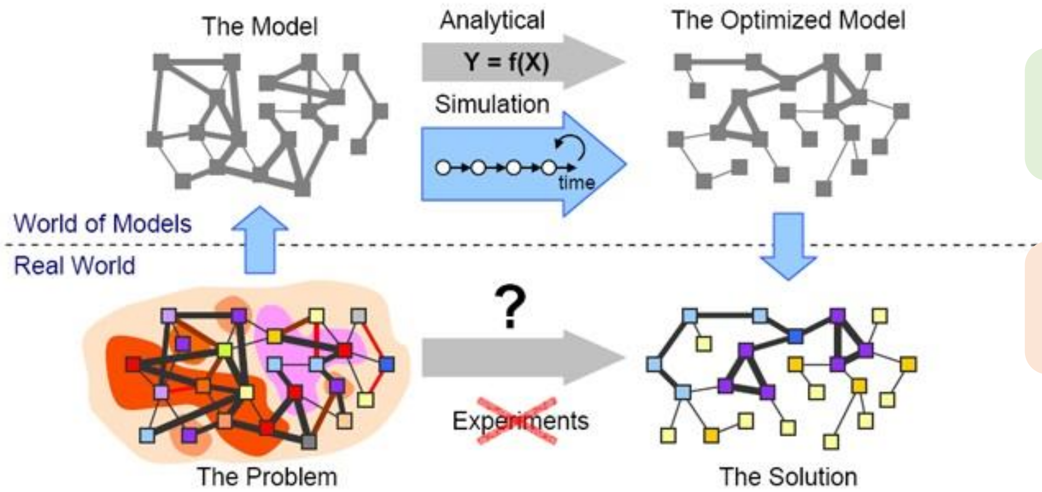
Simulation is all we NEED Here!

Simulations model the behavior of a system

Simulation can help when systems are not easy to describe mathematically or when historical data is not adequate for training or testing machine learning techniques. Instead of representing a complete system as a statistical algorithm or generating a fixed data set, simulation captures the characteristics and relationships of system components to provide a dynamic model

Pragmatic Prescriptive Analytics ➔ Simulation and Optimization





Simulation - How ?

Goal – to Build a Computational Model which resonates with the behavior of the Physical System

1. We need the Internal Logics of the Systems to be replicated
2. Input / Output Data
3. Assumptions and Risk involved in that
4. Validation with the historical
5. Common Template to replicate multiple systems

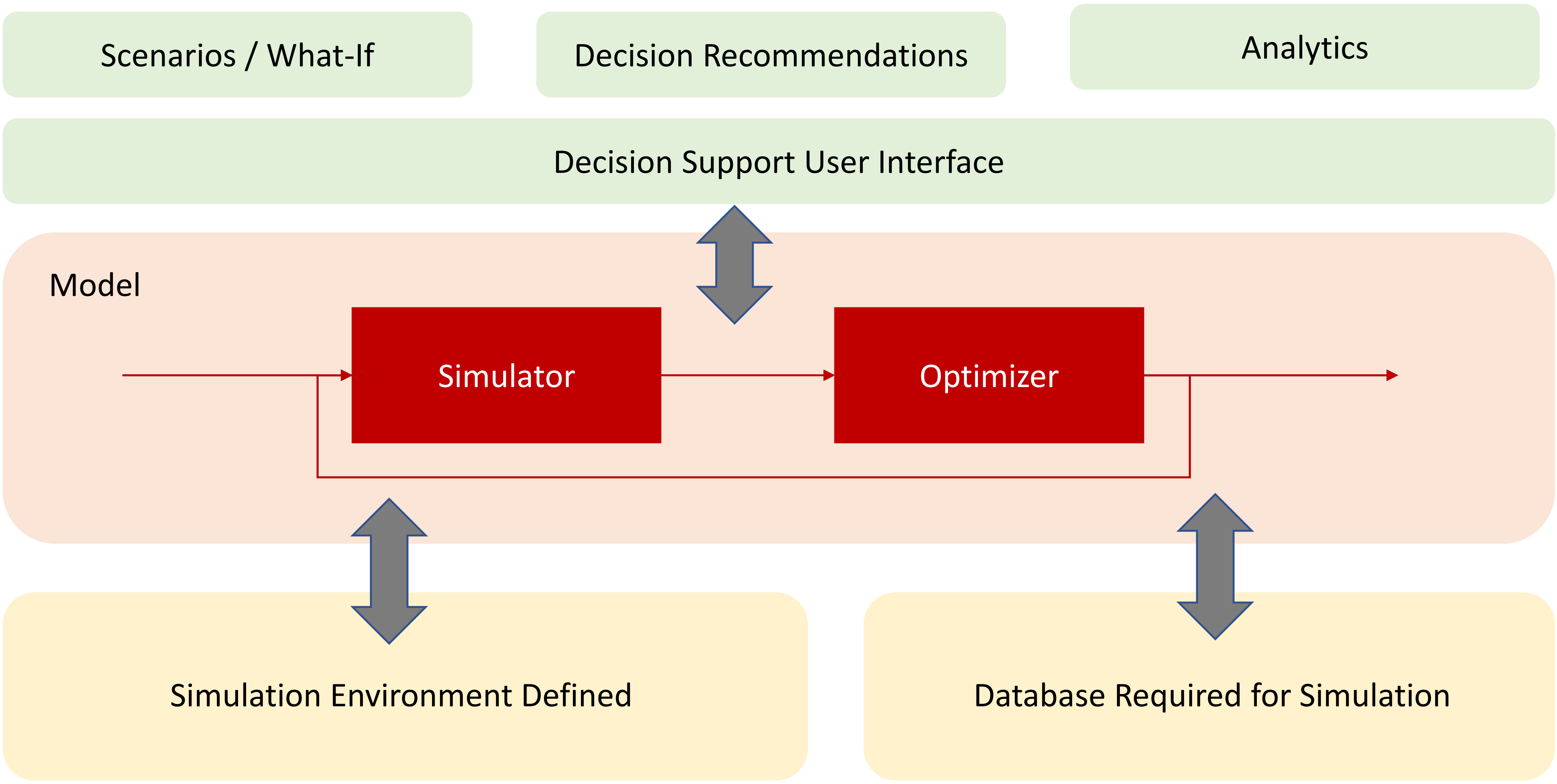
Simulation Models

Systems and Dynamics

Discrete Event Simulation

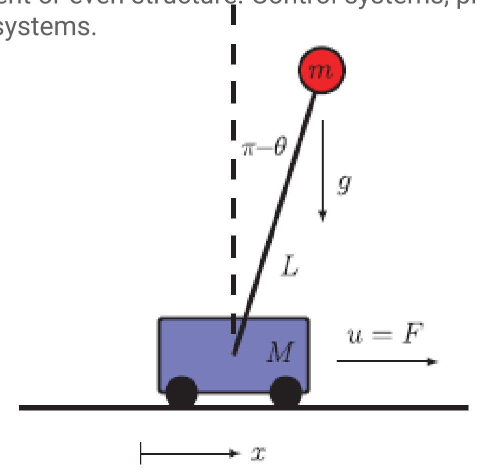
Agent Based Modeling

Pragmatic Prescriptive Analytics → Simulation and Optimization Work in Tandem → Decision Support System



Systems & Dynamics based Simulation – for Physical Systems

Dynamic systems are complex objects, whose behavior can be defined with algebraic and differential equations, as well as events that change model environment or even structure. Control systems, physical and mechanical objects, chemistry processes, signal processing are typical examples of such dynamic systems.



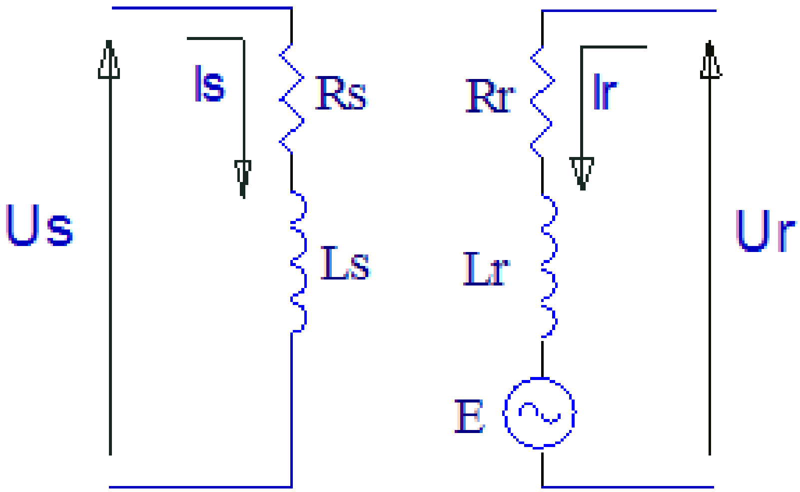
Represent

$$\dot{x} = v$$

$$\dot{v} = \frac{-m^2L^2 g cos(\theta)\sin(\theta) + mL^2(mL\omega^2\sin(\theta) - dv) + mL^2u}{mL^2(M + m(1 - cos(\theta)^2))}$$

$$\dot{\theta} = \omega$$

$$\dot{\omega} = \frac{(m + M)mglsin(\theta) - mlcos(\theta)(mL\omega^2\sin(\theta) - dv) + mlcos(\theta)u}{mL^2(M + m(1 - cos(\theta)^2))}$$



Represent

$$u_S = R_S \cdot i_S + L_S \cdot \frac{di_S}{dt} \quad , \qquad (1)$$

$$u_R = R_R \cdot i_R + L_R \cdot \frac{di_R}{dt} + \omega_m \cdot M_{SR} \cdot i_S \quad , \qquad (2)$$

$$m_C + m_m = J_m \cdot \frac{d\omega_m}{dt} + B_m \cdot \omega_m \quad , \qquad (3)$$

$$m_C = M_{SR} \cdot i_S \cdot i_R \quad , \qquad (4)$$

Discrete Event Simulation – for Systems with Actions and Events

Discrete Event Simulation is to Replicate a Real-World System which consists of logically separable process and events that autonomously progress through time. Each event occurs on a specific process and is assigned a logical time (a timestamp).

Example of a Production Process

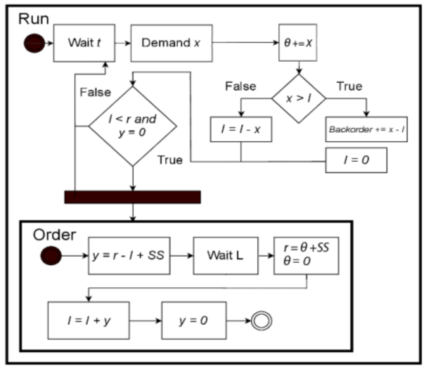
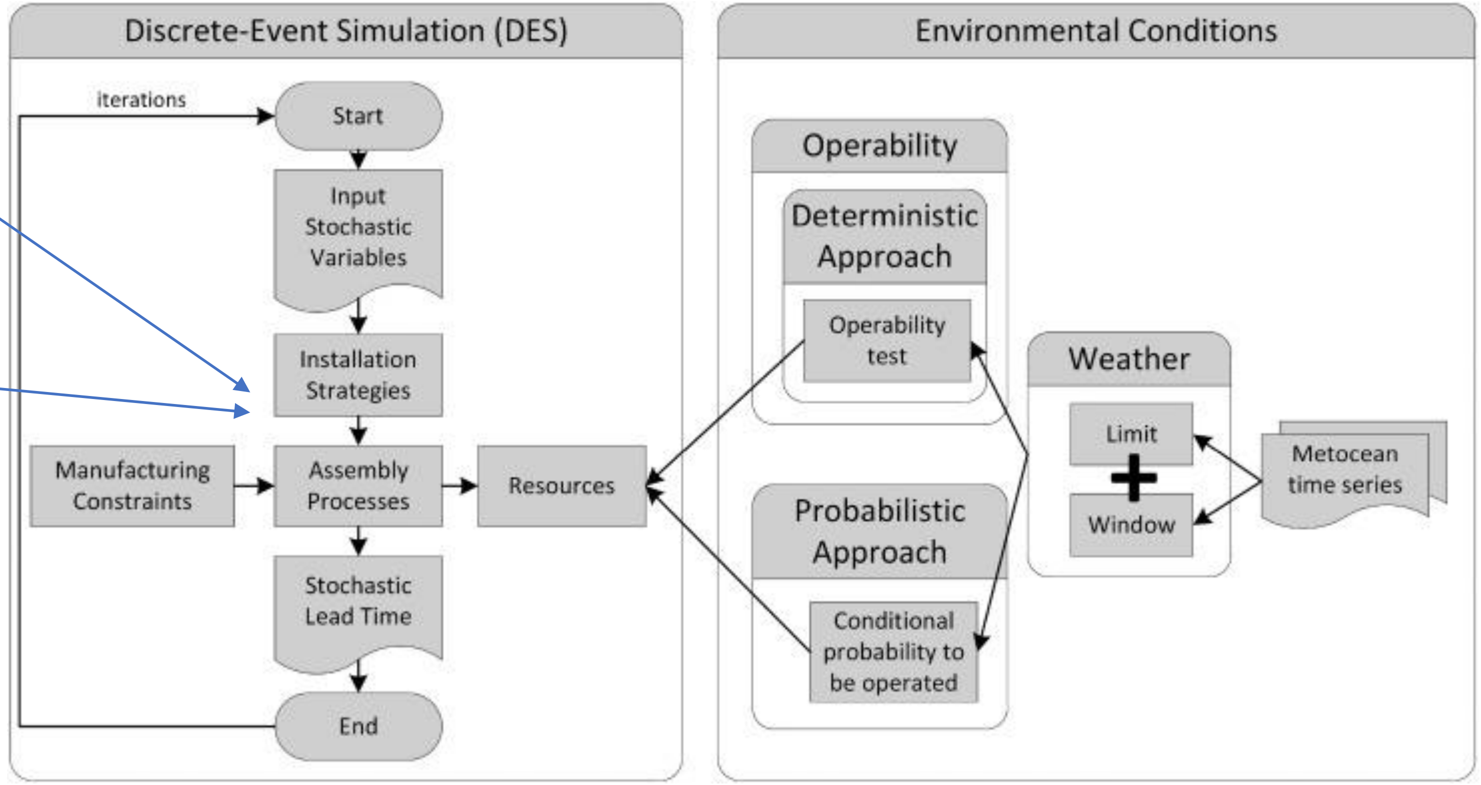


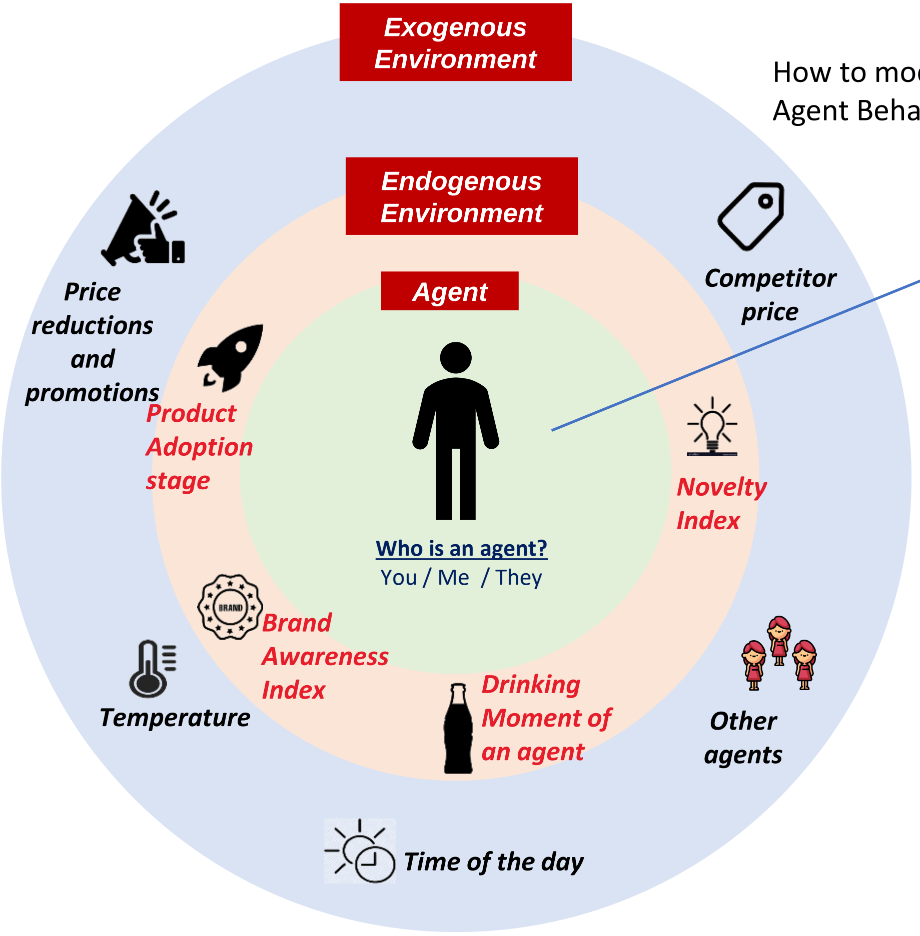
Illustration - Internal Logics of a Particular Process



Agent Based Simulation – for Systems with People and Places

Agent Based Modeling – Simulation of the real world

Interacting individual agents use their personalized properties and behaviors to simulate real world scenarios

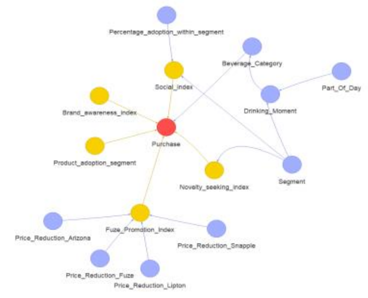


How to model Agent Behavior?

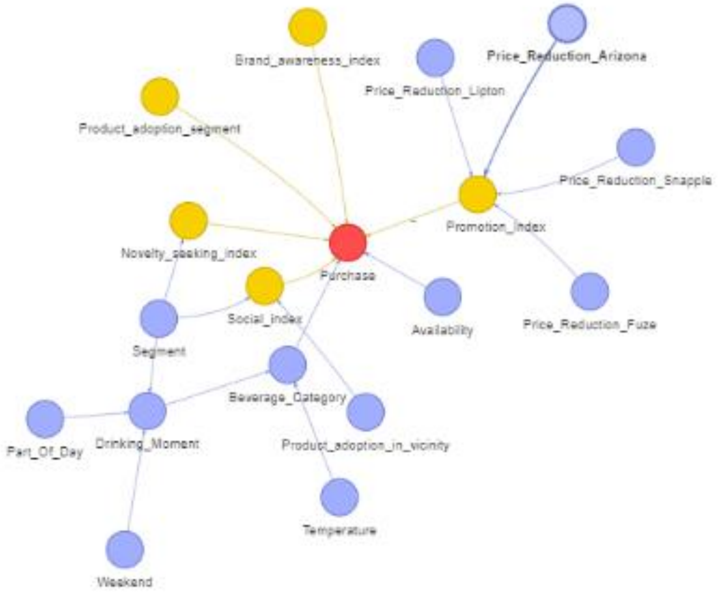
Agent Knowledge base

Agent Behavior and Actions

Heuristics



Bayesian Networks as the brain of each Agent which captures its behavior

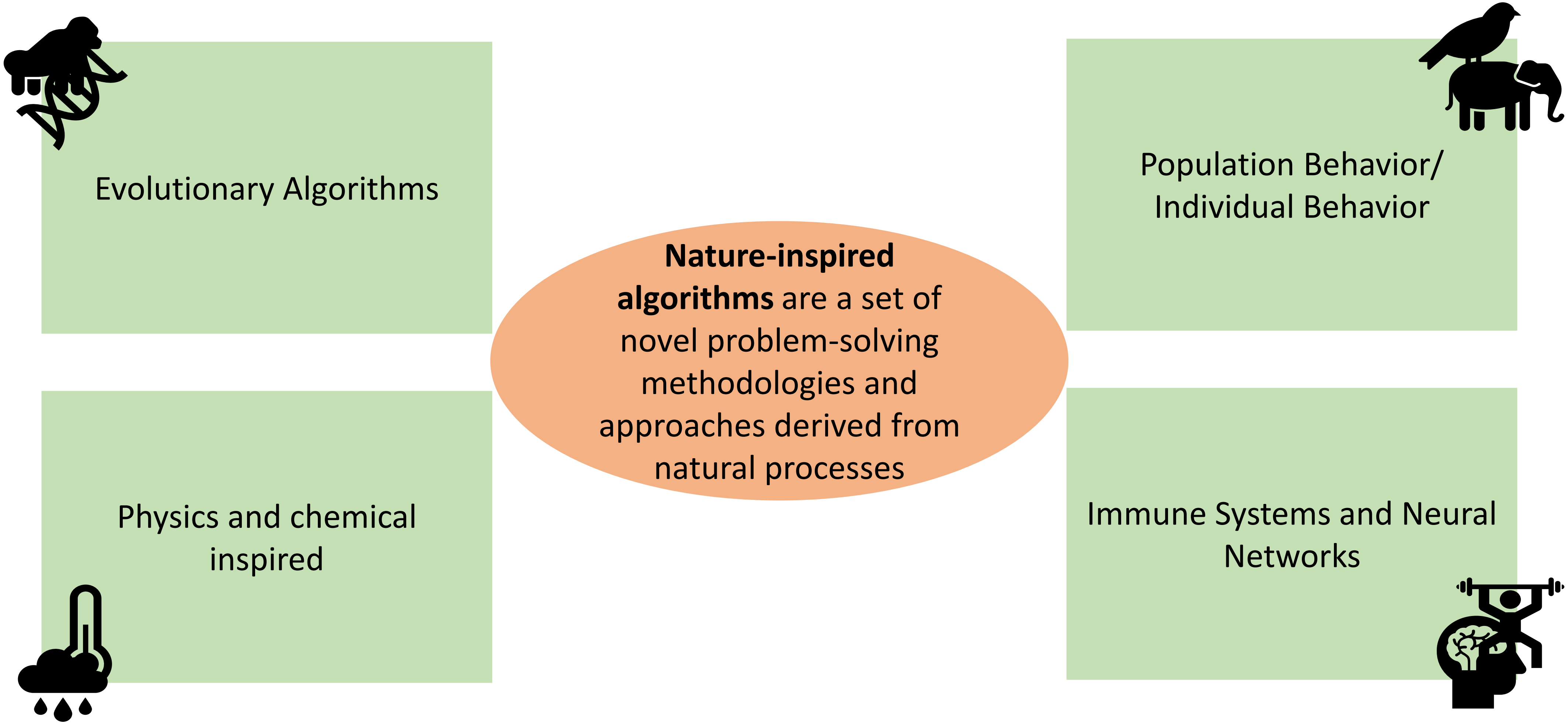


Bayesian Network – Brain of the agent

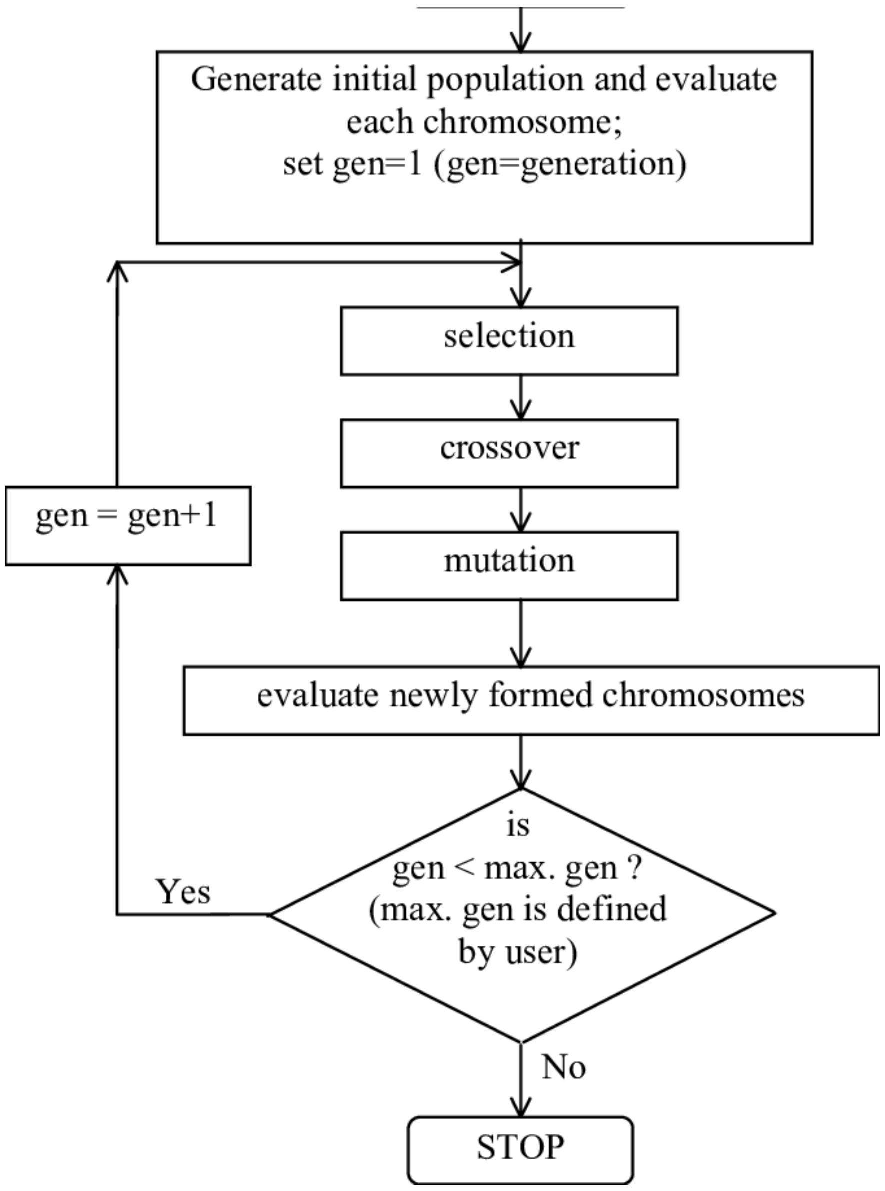
The graphical structure of the Bayesian network combined with the conditional probabilities forms the brain of an agent

Accelerated Prescriptive Intelligence for Complex Systems using Meta Heuristics Optimization

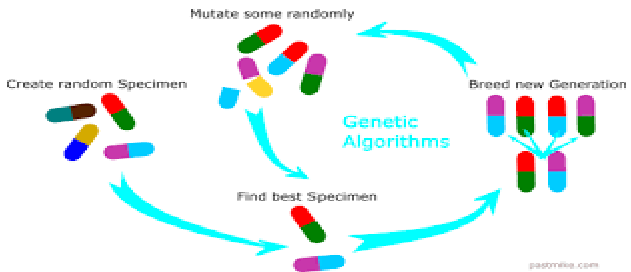
A metaheuristic algorithm is a search procedure designed to find, a good solution to an optimization problem that is complex and difficult to solve to optimality.



Genetic Algorithm : Flow chart



- Population : Set of Solutions
- Chromosomes : Each solution is a Chromosome
- Gene : Granular level of Chromosome.
- Selection : Process of selecting best fits to produce the new generation (Parental Chromosomes)
- Crossover : process of producing new off springs – Children
- Genotype and Phenotype
- Mutation : Changes in Gene for maintaining the diversity from one generation to another



Use Cases

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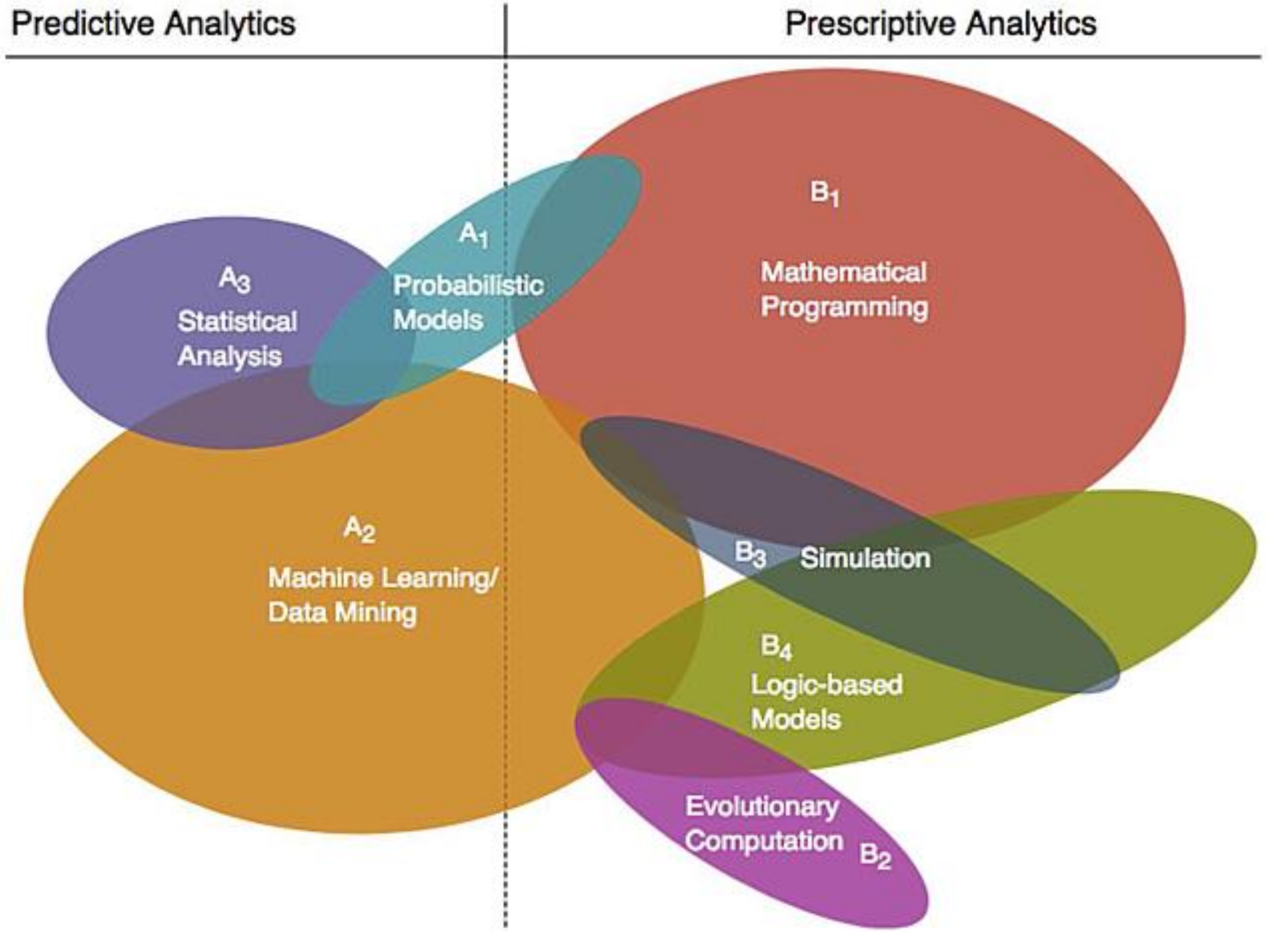


Questions!

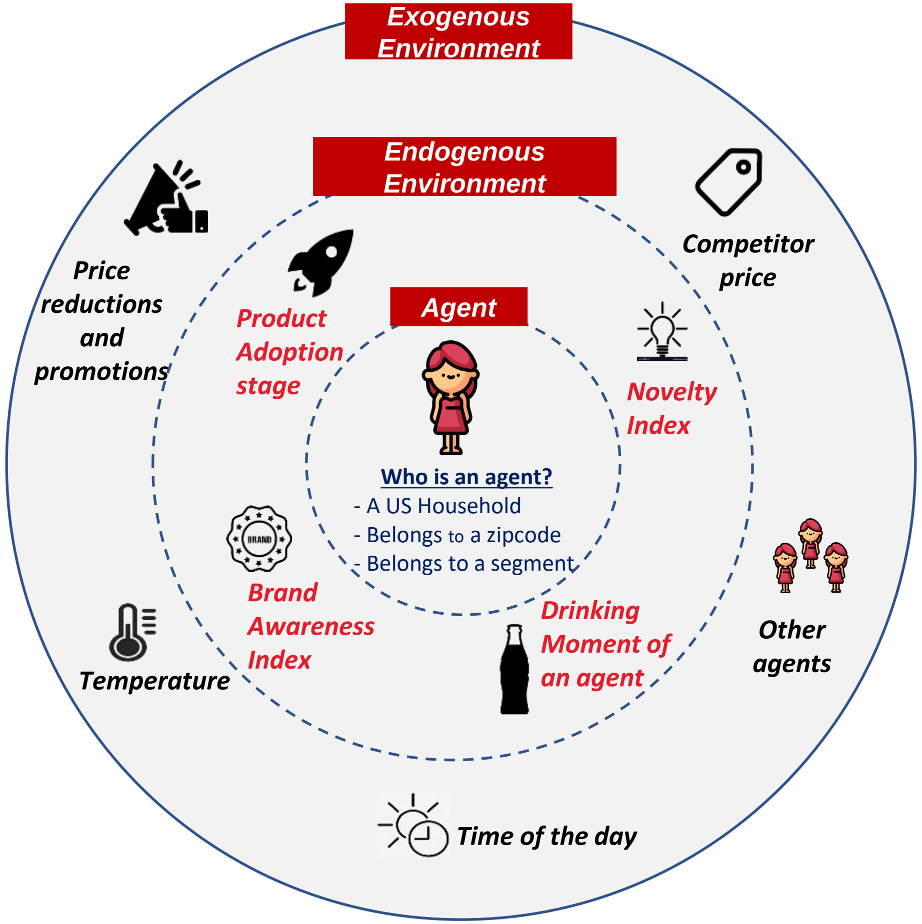
Thank you!

Appendix

Agent Based Simulation – for Systems with People and Places

Agent Based Modeling – Simulation of the real world

Interacting individual agents use their personalized properties and behaviors to simulate real world scenarios



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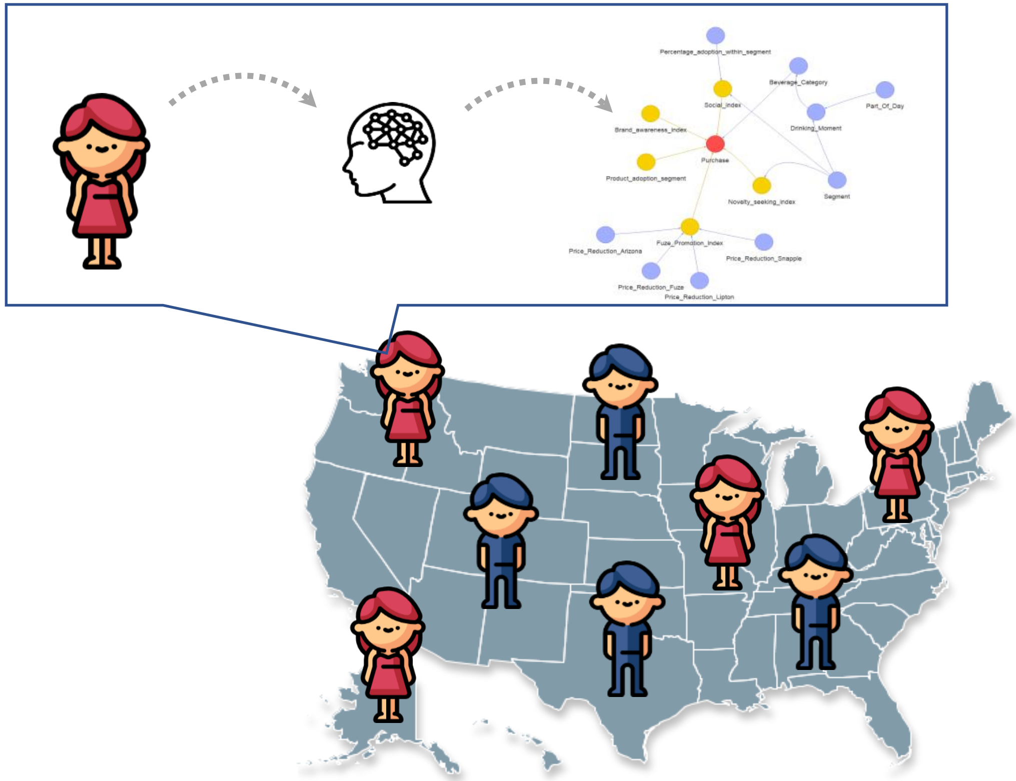

What-if scenarios

Multiple what-if scenarios can be performed by tweaking the levers provided

Levers:

- Product Price
- Promotions
- Marketing Spends