FRAMEWORK FOR MULTI-AGENT SIMULATION OF USER BEHAVIOUR IN E-COMMERCE SITES

FINAL PDIS PRESENTATION

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TOPICS

- Context
- Objectives
- Literature Review
  - E-commerce Background
  - Simulation
  - Probabilistic Models
- Methodology & Approach
- Work Plan
- Annexes

CONTEXT

- Customers interact with e-commerce websites in different ways
- Companies want to optimize success metrics (CTR, CPC, …) for profit
- Changing what, how and when content (ads, recommendations, …) is displayed influences customers' interactions

- Summarizing and analysing this behaviour is expensive, hard, tricky, …
- Data scientists need to resort to online techniques with a high operational cost

OBJECTIVES

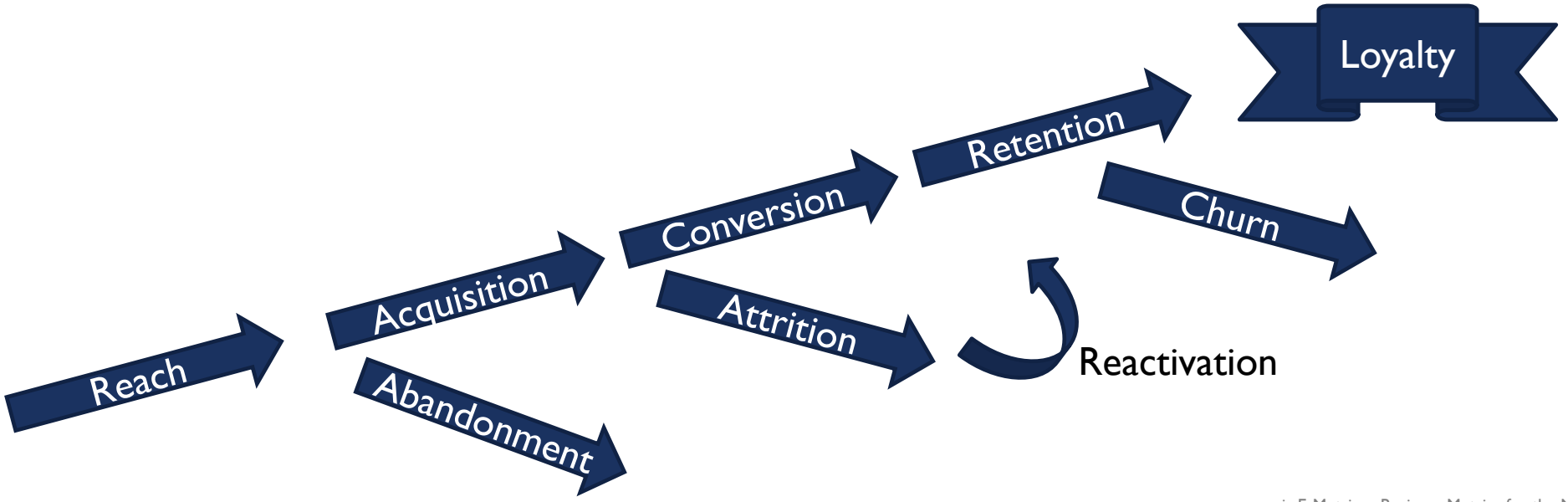
- Design and development of a simulation framework
- Given data from **website structure** and **content**, **usage** and **user profiles**,
  run a simulation where each entity represents a person interacting with the website
- Support extensible models and rules

E-COMMERCE BACKGROUND

in shail.me

3 de fevereiro de 2016

CUSTOMER LIFECYCLE



in E-Metrics: Business Metrics for the New Economy

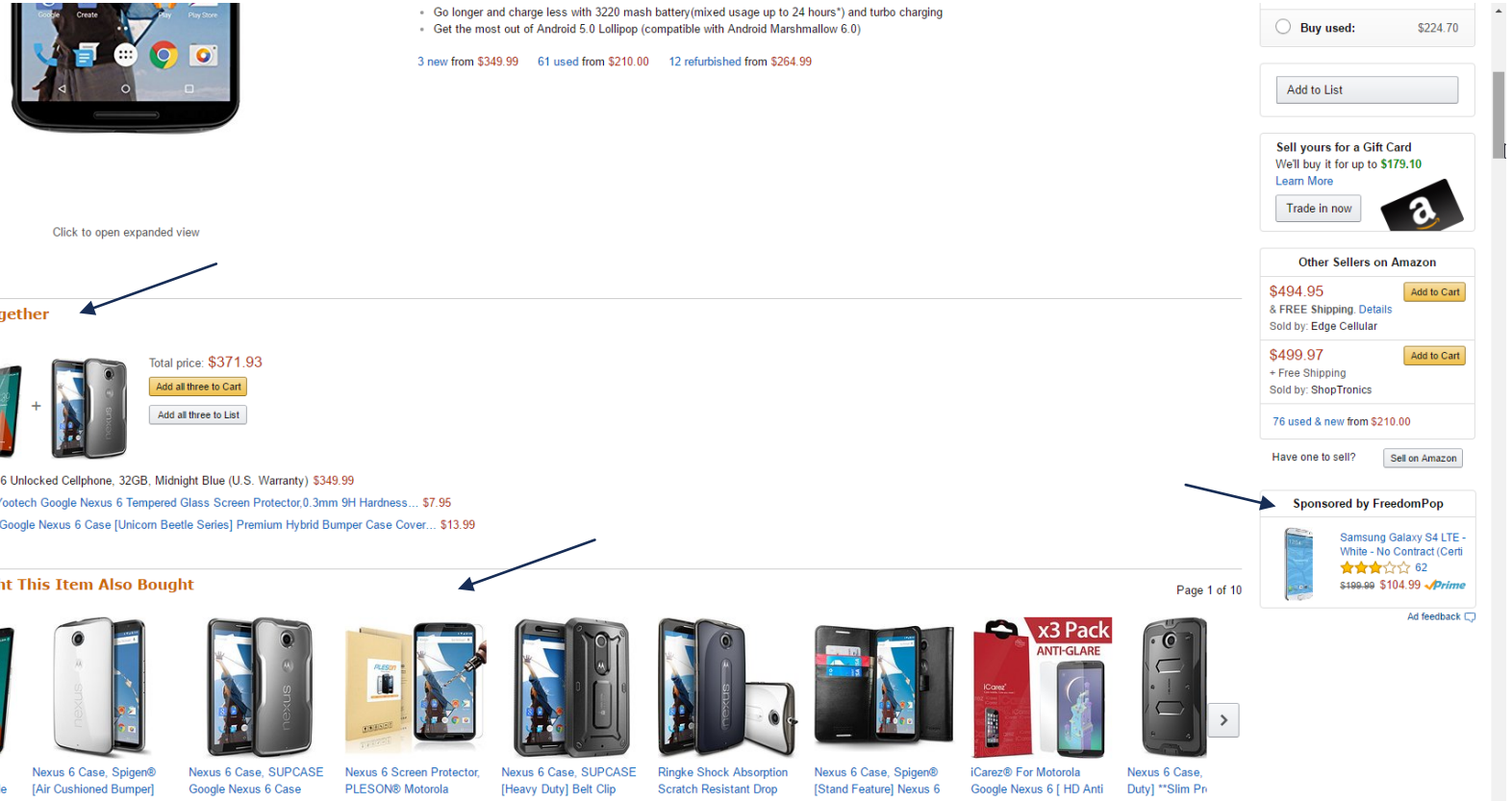
E-COMMERCE METRICS

- **Customer Metrics**
  - Recency
  - Frequency
  - Monetary Value
  - Duration
  - Yield
- **Promotion Calculations**
  - Acquisition Cost
  - Cost per Conversion
  - Net Yield
  - Connect Rate
- **Customer Behaviour**
  - Stickiness
  - Slipperiness
  - Focus
  - Velocity
- **Others**
  - Personalization Index
  - Life Time Value
  - Loyalty Value
  - Freshness Factor

in E-Metrics: Business Metrics for the New Economy

INFLUENCING USER BEHAVIOUR

E-Commerce Background



in Amazon.com, Nexus 6 product page

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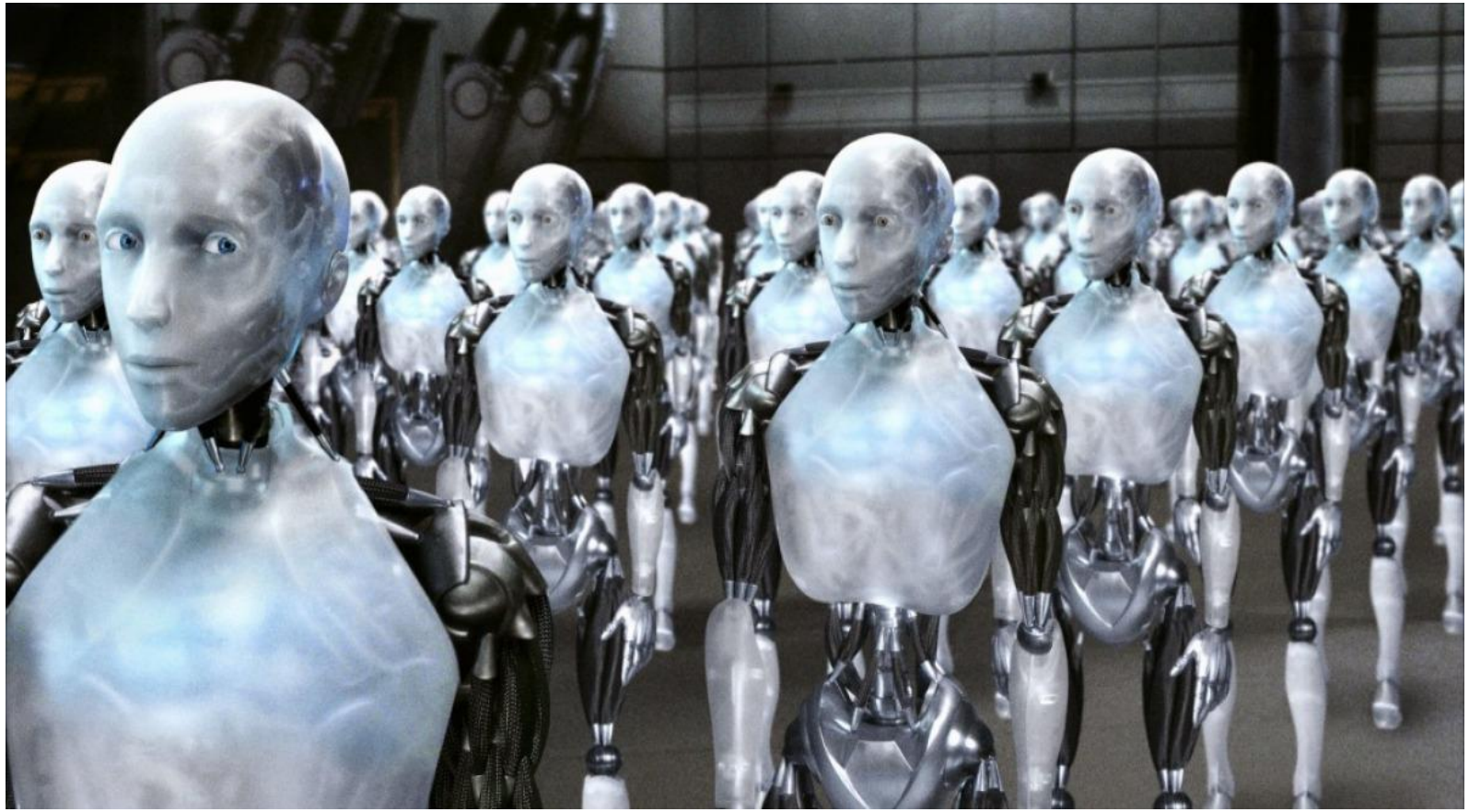
SIMULATION

MULTI-AGENT SYSTEMS



I, Robot - 20th Century Fox

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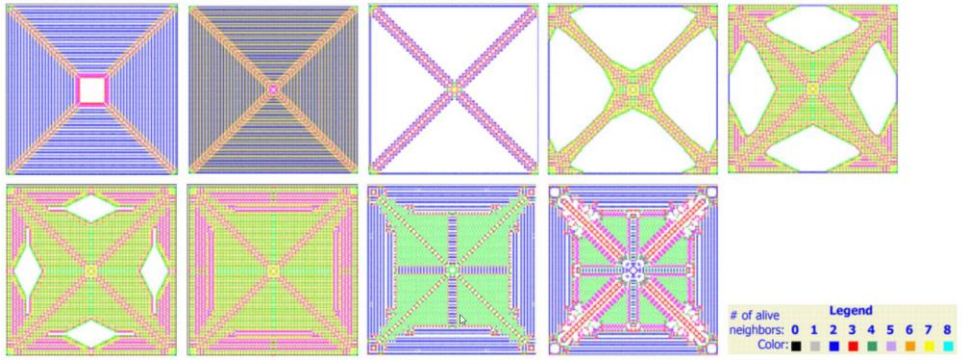
AGENT BASED SIMULATION (ABS)

- Simulating the actions and iteractions of autonomous agents
- Individual-based models (IBMs) ← Ecology

- Agents as objects
- Emergence
- Complexity

1. Complex Network Modeling Level
2. Exploratory Agent-based Modeling Level
3. Descriptive Agent-based Modeling (DREAM)
4. Virtual Overlay Multiagent system (VOMAS)

- [Niazi, M. A. K. (2011). Towards A Novel Unified Framework for Developing Formal , Network and Validated Agent-Based Simulation Models of Complex Adaptive Systems, 275.]



Variation patterns of Conway's Game of Life (Chan et al., 2010)

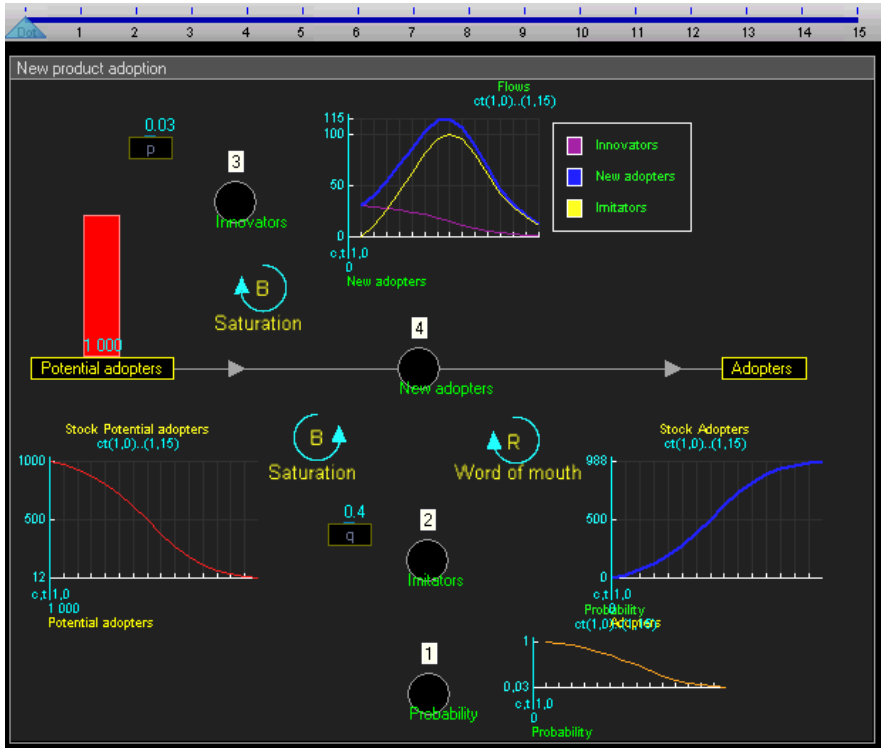
SYSTEM DYNAMICS (SD)

Simulation

- **Stocks** – basic stores of objects
- **Flows** – movement of objects between stocks
- **Delays** – time between cause and effect
- Internal **feedback loops**

- Usually deterministic, macroscopic and continuous

[Maidstone, Robert; 2010; Lancaster Univerisity]



Dynamic Stock and flow diagram of Adoption model (Sterman, 2001) Patrhoue, 2009 – software TRUE

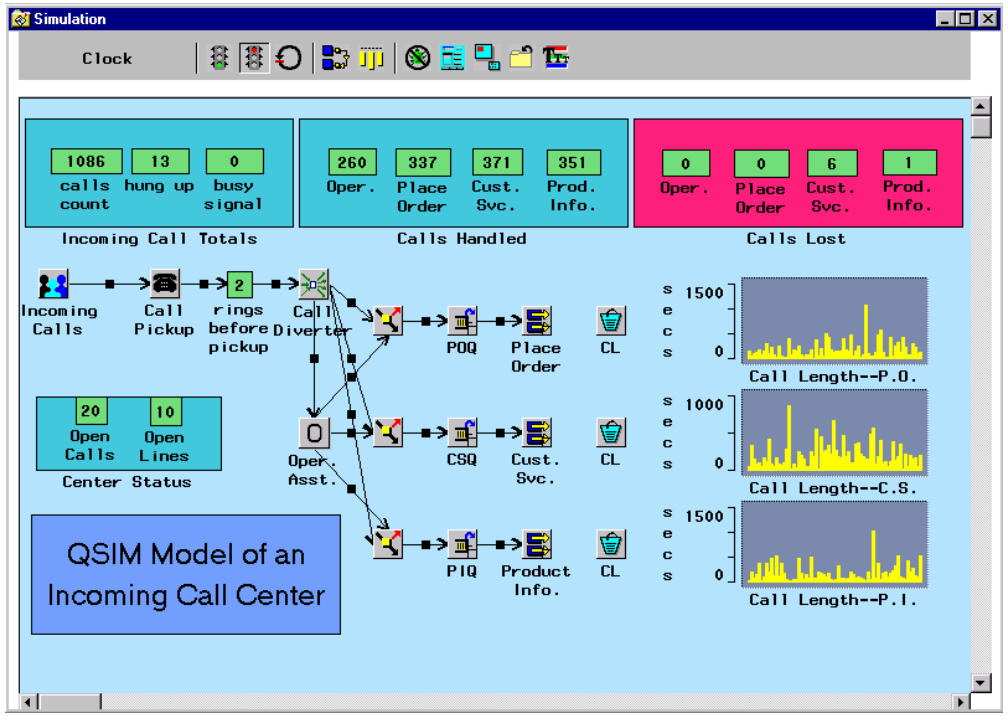
DISCRETE EVENT SIMULATION (DES)

- Models a sequence of discrete events
- Events mark a change of state

- Discrete simulation (and time), stochastic and microscopic
- Network of queues

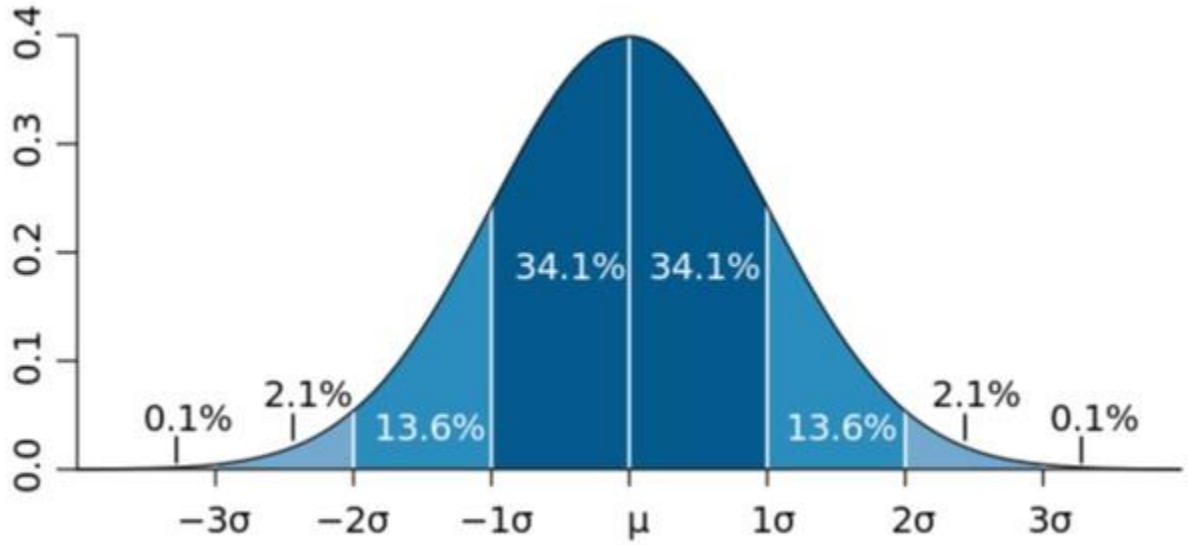
1. Jump to the next chronological event
2. Execute uncondional events (B type)
3. Execute conditional events (C type)

[Pidd, 1998]



QSIM Application © SAS Institute Inc.

PROBABILISTIC MODELS

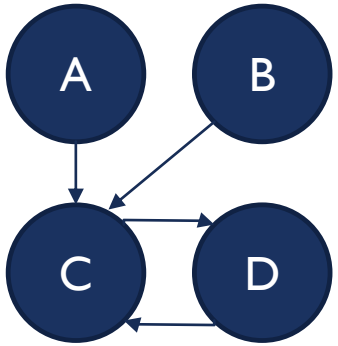


OptionsAnnex.com, 2013; Normal Distribution

PROBABILISTIC GRAPHICAL MODELS

- Conditional dependence structure between random variables

- **Baysian networks**
- **Markov network** (Markov random field)
- Factor graph
- Clique tree
- ...



Example of a graphical model

BAYESIAN NETWORKS

Probabilistic Models

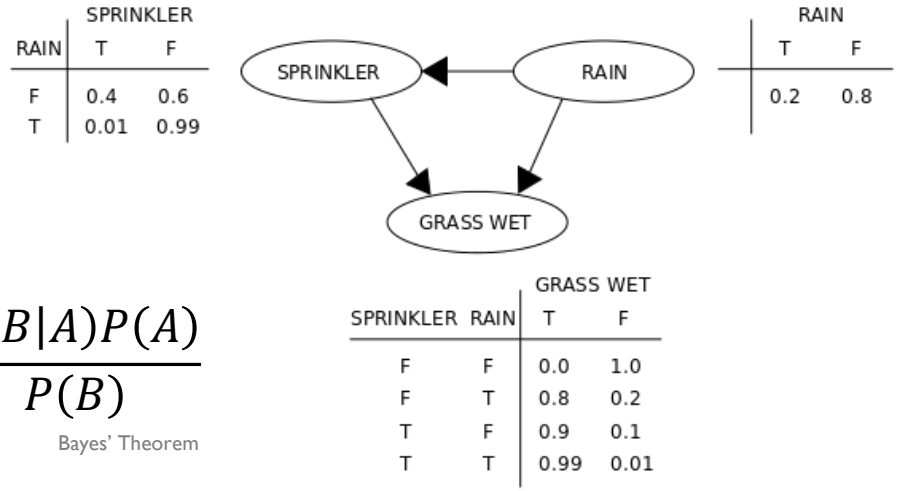
- Directed Acyclic Graph
  - Random variables with conditional dependencies
- Handle incomplete data sets
- Combination of domain knowledge and data

[Heckerman, D. (1996). A Tutorial on Learning With Bayesian Networks.

Innovations in Bayesian Networks, *1995*(November), 33–82.]

$$P(A|B) = \frac{P(B|A)P(A)}{P(B)}$$

Bayes' Theorem



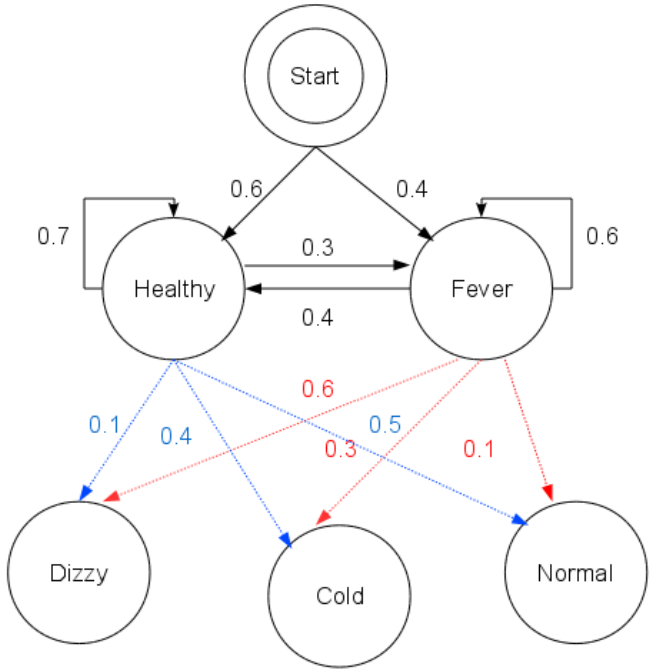
Example of a baysian network, AnAj, 2006

(HIDDEN) MARKOV MODELS

Probabilistic Models

- Dynamic Bayesian Networks → model time series
- Markov chain → current state independent of previous states (memoryless)

- HMMs
  - Unobserved states
  - Visible observations



Example of a HMM, Reelsun, 2012

[Rabiner, L. R. (1989). A tutorial on hidden Markov models and selected applications in speech recognition. *Proceedings of the IEEE*.]

METHODOLOGY & APPROACH

- Start with DES with HMM
- Observations in HMM → actual interactions of each user (click, buy, leave, ...)
- Hidden states → State of mind of the user (likely to buy, not likely, going to leave, ...)

- Experiment, analyse and compare multiple models

- **Testing**
  - Given data from a real website, verify that the simulation is similar to what *happened*

WORK PLAN

- Done
  - Literature review regarding e-commerce, simulation and probabilistic models
  - Initial experiments/prototypes in modelling (e.g implementation of Viterbi algorithm, simple DES)
- 1 week (15/02 – 19/02)
  - Dissertation web page
  - Further initial experiments
- 4 weeks (19/02 – 17/03)
  - Basis/foundation of the framework
- 6 weeks (11/03 – 21/04)
  - Experimental and iterative scenarios and models
- 2 weeks (25/04 – 06/05)
  - Integration with other tools
- 4 weeks (09/05 – 03/06)
  - Tests and validation
- 5 weeks (06/06 - 15/07)
  - Dissertation writing
  - Defense and submission

ANNEXES

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COMPARISON OF SIMULATION PARADIGMS

Annexes

System Dynamics (SD)	Discrete-event Simulation (DES)	Agent-based Simulation
System-oriented; focus is on modeling the system observables	Process-oriented; focus is on modeling the system in detail	Individual-oriented; focus is on modeling the entities and interactions between them
Homogenized entities; all entities are assumed have similar features; working with average values	Heterogeneous entities	Heterogeneous entities
No representation of micro-level entities	Micro-level entities are passive 'objects' (with no intelligence or decision making capability) that move through a system in a prespecified process	Micro-level entities are active entities (agent) that can make sense the environment, interact with others and make autonomous decisions
Driver for dynamic behavior of system is "feedback loops".	Driver for dynamic behavior of system is "event occurrence".	Driver for dynamic behavior of system is "agents' decisions & interactions".
Mathematical formalization of system is in "Stock and Flow"	Mathematical formalization of system is with "Event, Activity and Process".	Mathematical formalization of system is by "Agent and Environment"
handling of time is continuous (and discrete)	handling of time is discrete	handling of time is discrete
Experimentation by changing the system structure	Experimentation by changing the process structure	Experimentation by changing the agent rules (internal/interaction rules) and system structure
System structure is fixed	The process is fixed	The system structure is not fixed

Behzad Behdani. 2012. Evaluation of paradigms for modeling supply chains as complex socio-technical systems

MARKOV MODELS

Annexes

	System state is fully observable	System state is partially observable
System is autonomous	Markov chain	Hidden Markov model
System is controlled	Markov decision process	Partially observable Markov decision process