14th International Model-Driven Requirements Engineering (MoDRE) Workshop

A Goal-Oriented Approach for Modeling Decisions in ML Processes

Rohith Sothilingam & Eric Yu

Outline of this Presentation

- **Background, Purpose, & Motivation**
- Conceptual Modeling
  - Analyzing Tradeoffs in ML Design
  - Introducing the Conceptual Modeling Notation
  - Analyzing Tradeoffs in ML Design across Iterative Stages
- Related Work
- Conclusions & Future Work

Purpose & Motivation

Purpose: To inform and guide decision-making during the design of iterative ML processes

Motivation: Existing goal modeling notations are limited in their ability to express the following:

- Making adjustments on decisions on chosen techniques to achieve eventual goal
- Consideration for non-intentional factors as decision input to aid us in our design

What we propose: 3 modeling constructs that support the following:

- **Sensors:** Support collecting information from the causal world (Sensors)
- **Actuators:** Tweak techniques (tasks) based on input from Sensors
- **Iterative Loops:** Express iterative, nested loops and the tradeoffs within each

Outline of this Presentation

- Background, Purpose, & Motivation
- Conceptual Modeling
  - **Analyzing Tradeoffs in ML Design**
  - Introducing the Conceptual Modeling Notation
  - Analyzing Tradeoffs in ML Design across Iterative Stages
- Related Work
- Conclusions & Future Work

Importance of Design Decision Points in ML Development

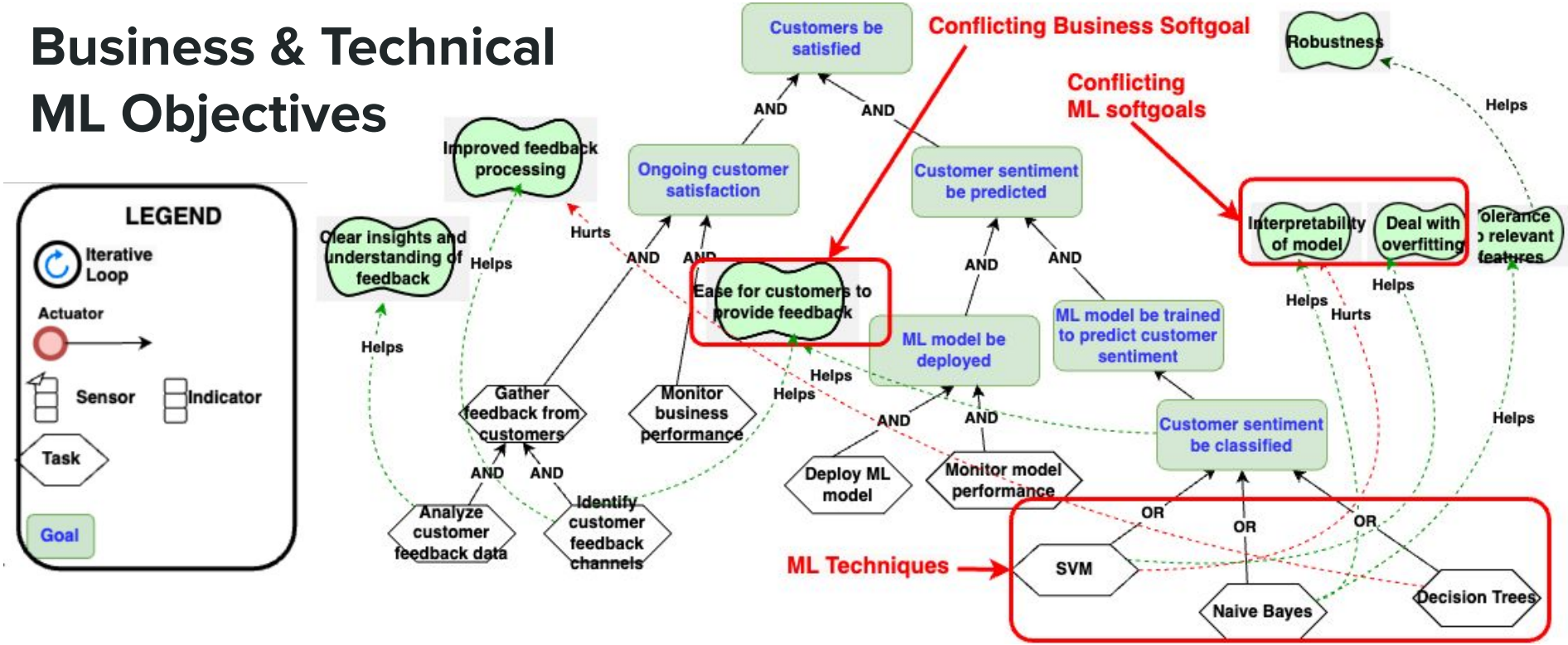
- **Decision points:** Steps in a process that ask questions about techniques or evaluation criteria.
- **Nested cycles:** Iterative ML development processes with interacting decision points.
- **Goal-oriented conceptual modeling:**
  - Supports ML process design
  - Guides decisions for each repetition
  - Aligns with ML model development objectives

ML Scenario

Consider the following Customer Feedback System Development Scenario:

- **Technical Goal:** Maximize sentiment analysis accuracy using either of the following ML modeling techniques: SVM, k-NN, or Naive Bayes.
- **Business Goal:** Improve ease of customer feedback
- **Conflict:**
  - SVM requires extensive labeled training data
  - SVM is sensitive to data noise and outliers
- **Tradeoff Needed:**
  - Balance accuracy and ease of use
  - Consider alternative algorithms or features

Tradeoffs Between Business & Technical ML Objectives



This Goal Model conveys an example of tradeoffs that can occur between **Business** and **Machine Learning Goals**, to achieve customer satisfaction.

The Missing Piece: Modeling Iterative cycles

- Iterations are a crucial aspect of Machine Learning development, yet unaccounted for in traditional goal modeling
- The ability to account for iterations and analyze how technical ML and Responsible AI objectives interact with each other across iterations is a core contribution of our work.

Outline of this Presentation

- Background, Purpose, & Motivation
- Conceptual Modeling
  - Analyzing Tradeoffs in ML Design
  - **Introducing the Conceptual Modeling Notation**
  - Analyzing Tradeoffs in ML Design across Iterative Stages
- Related Work
- Conclusions & Future Work

Conceptual Modeling Notation

The following captures the proposed conceptual modeling **notation** conveying Sensors, Actuators, and Iterative Loops

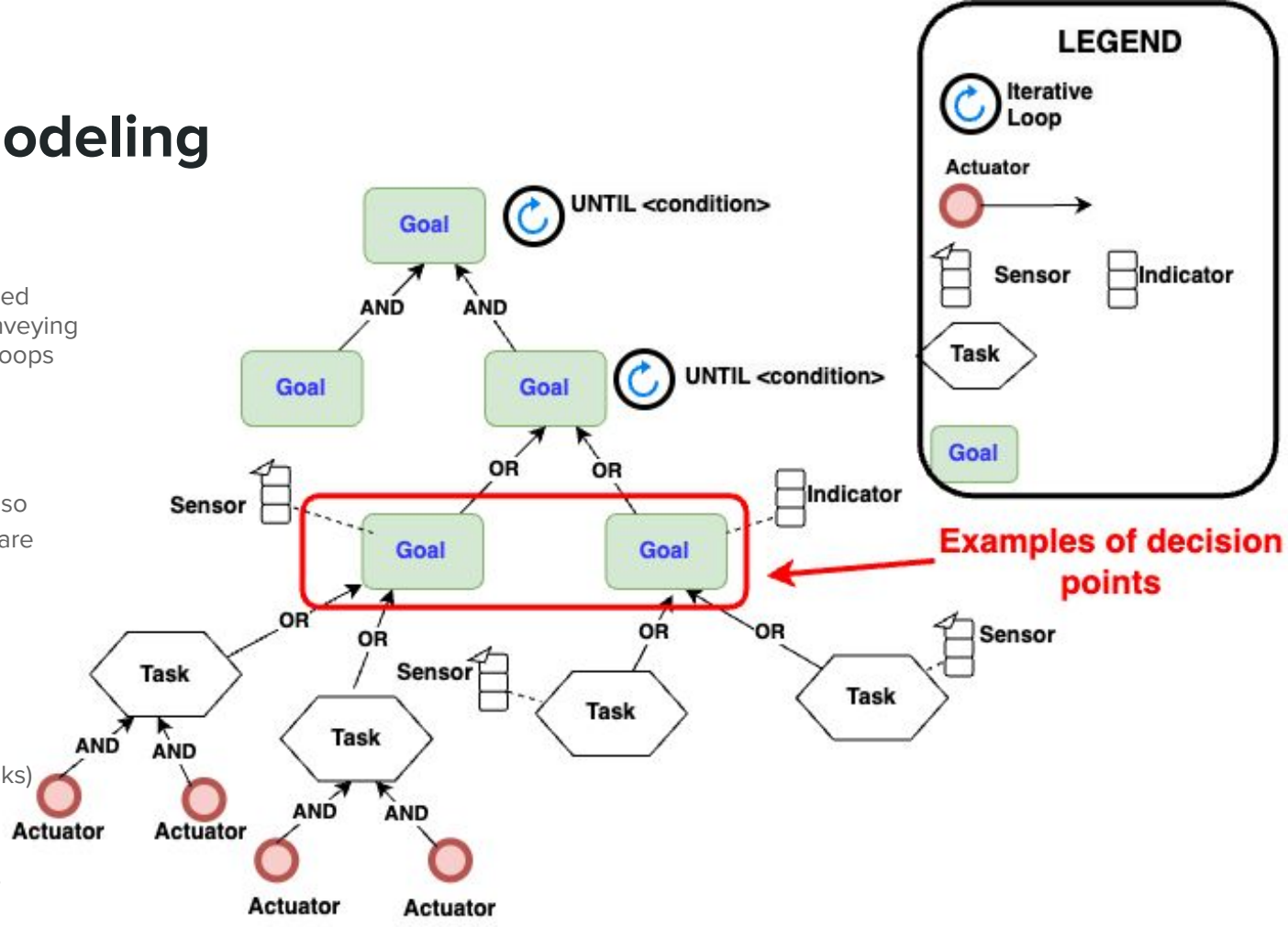
Tasks: one possible way of achieving the goal

Indicators: associated with goals so as to indicate how well the goals are achieved.

Sensors: Support collecting information from the causal world (Sensors)

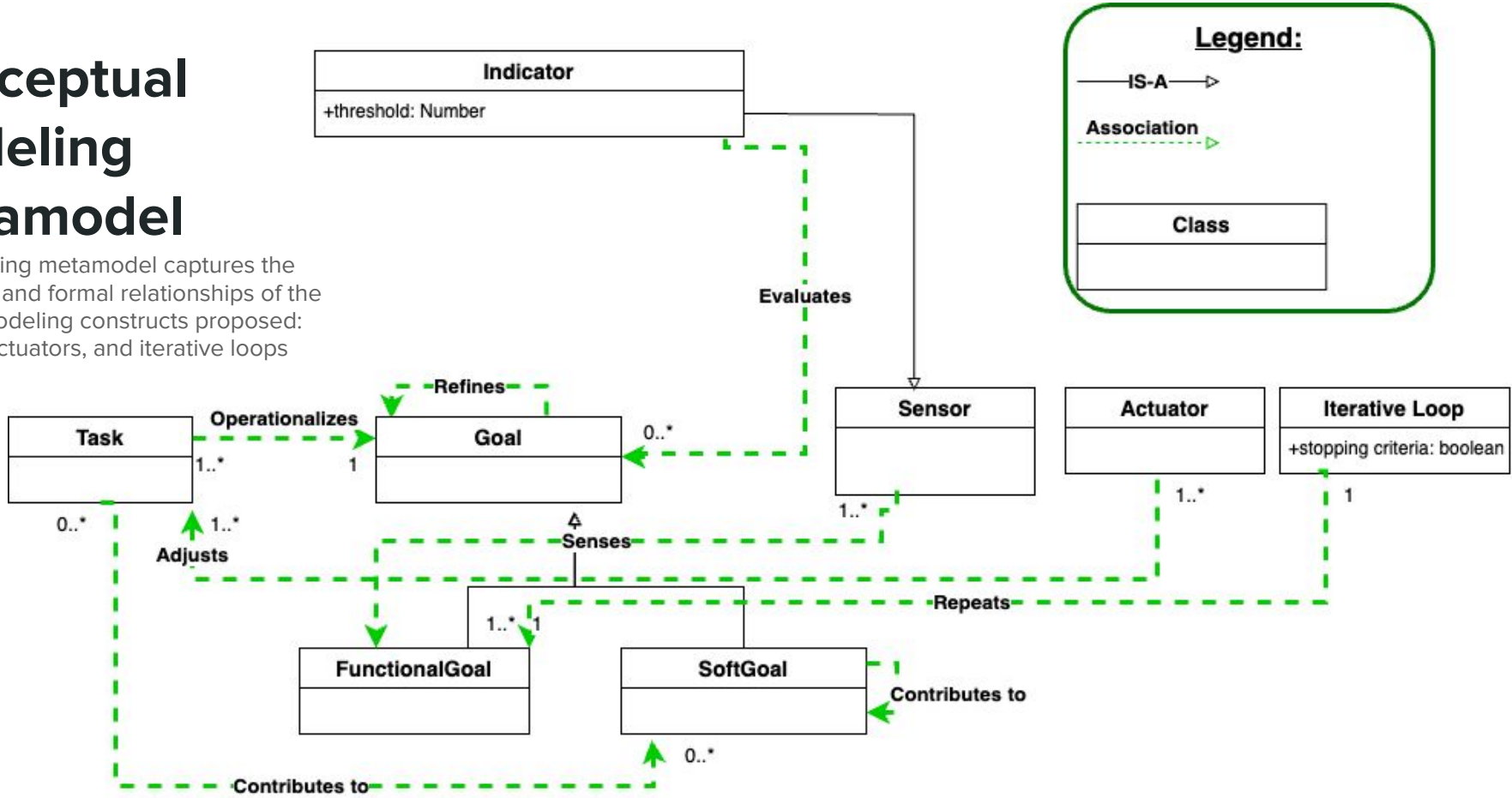
Actuators: Tweak techniques (tasks) based on input from Sensors

Iterative Loops: Express iterative, nested loops and the tradeoffs within each

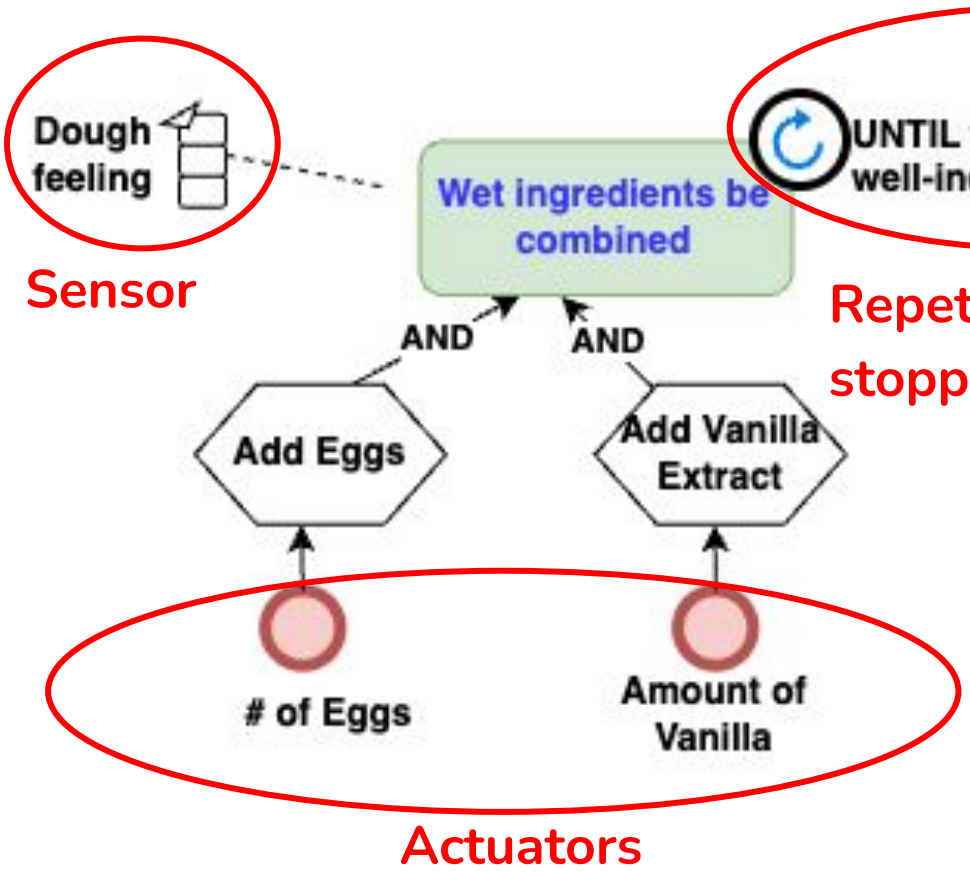


Conceptual Modeling Metamodel

The following metamodel captures the semantics and formal relationships of the primary modeling constructs proposed: sensors, actuators, and iterative loops



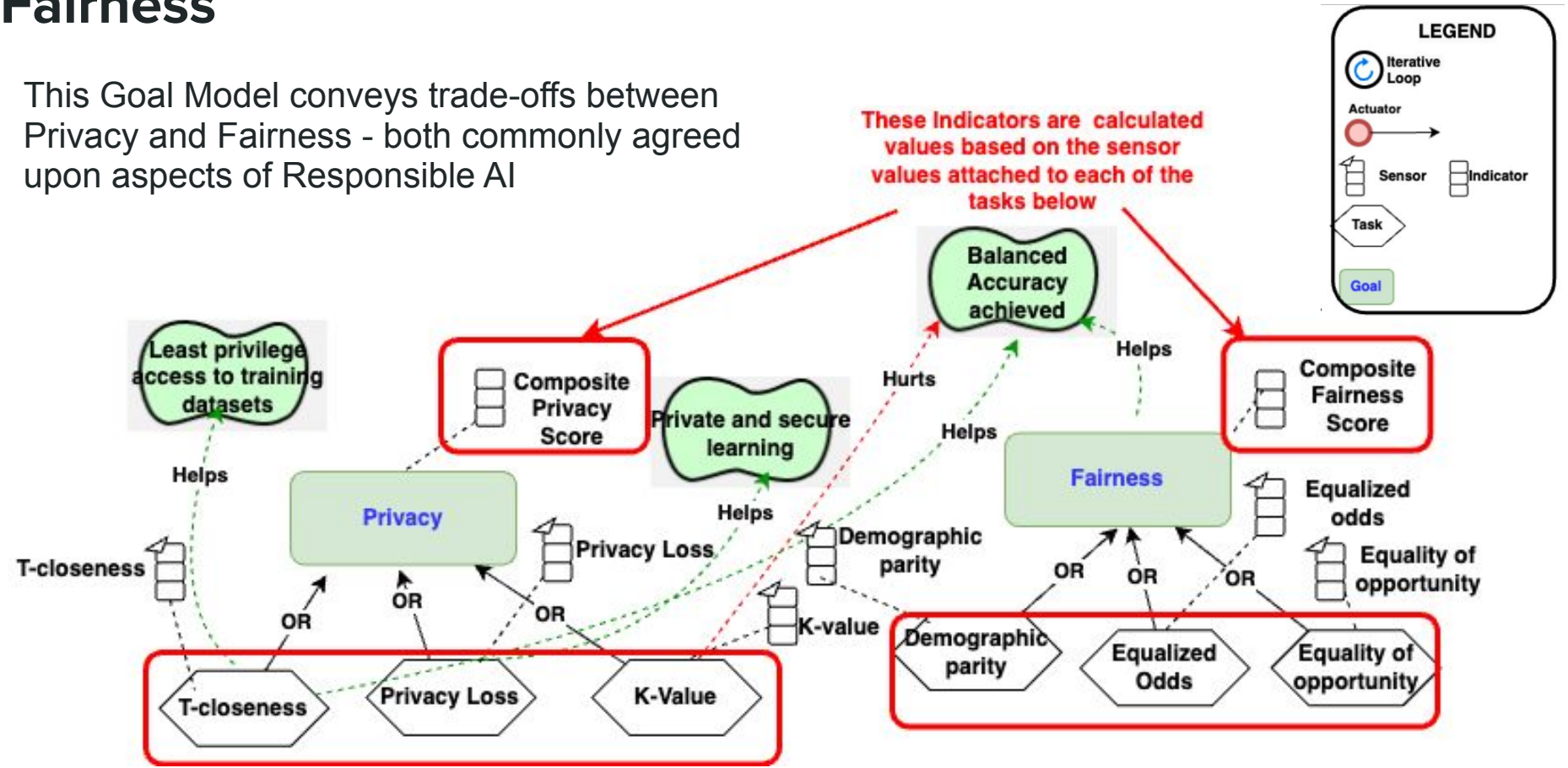
A Toy Example for Simple Iterative Processes



- Goal [***Wet ingredients be combined***] is ***REPEATED*** iteratively ***UNTIL*** the ***stopping criteria*** is met: “wet ingredients are well-incorporated”.
- Sensor [***Dough feeling***] provides an *input* to determine when the stopping criteria has been met.
- Actuators [***# of Eggs*** and ***Amount of vanilla***] can be tweaked based on the Sensor input to achieve the Goal ***UNTIL*** the loop is satisfied.

Tradeoffs between aspects of Responsible AI: Privacy vs. Fairness

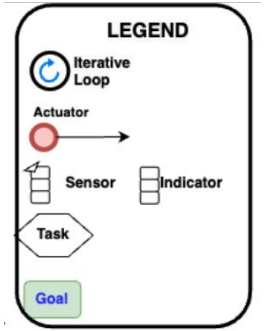
This Goal Model conveys trade-offs between Privacy and Fairness - both commonly agreed upon aspects of Responsible AI



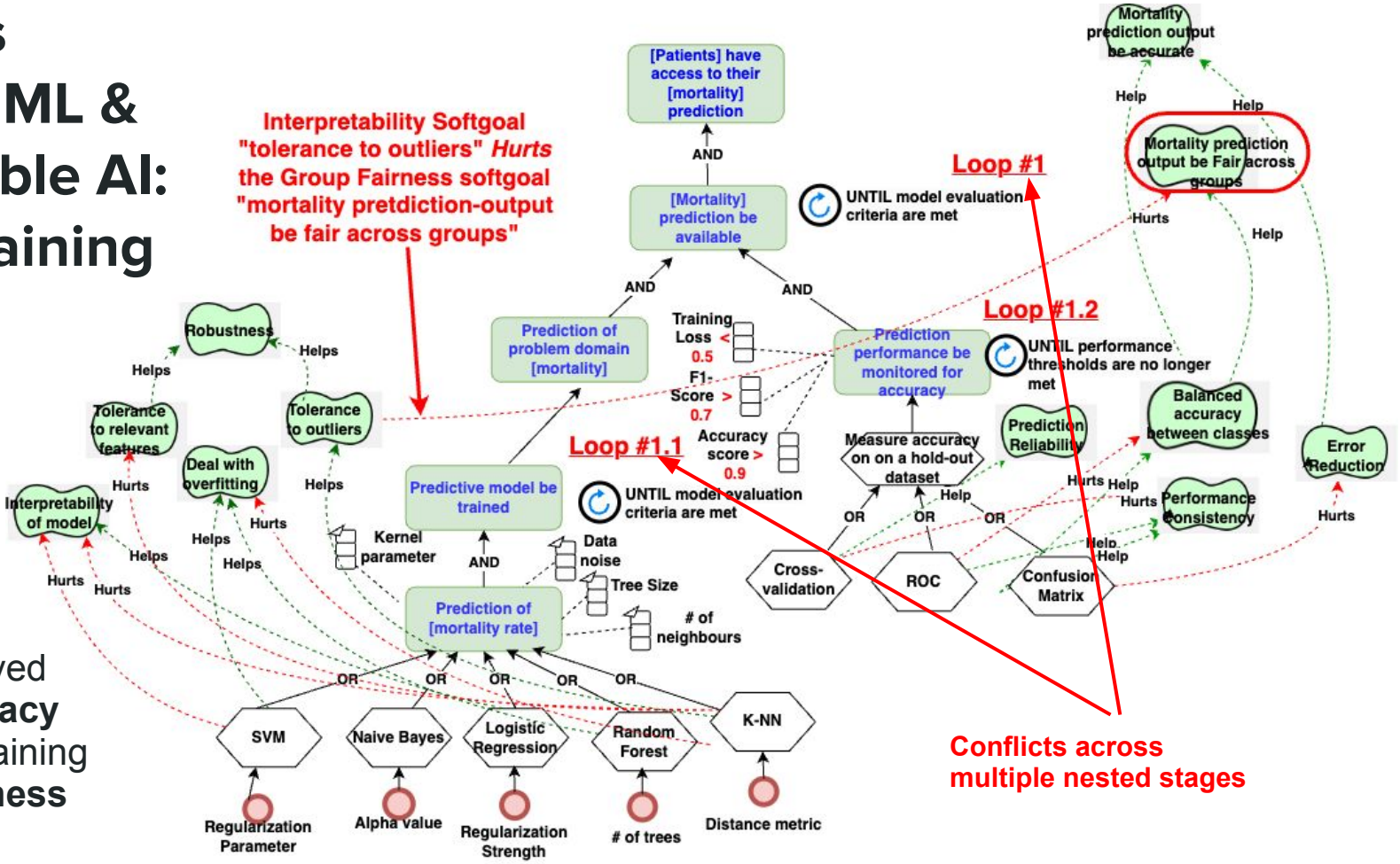
Outline of this Presentation

- Background, Purpose, & Motivation
- Conceptual Modeling
  - Analyzing Tradeoffs in ML Design
  - Introducing the Conceptual Modeling Notation
  - **Analyzing Tradeoffs in ML Design across Iterative Stages**
- Related Work
- Conclusions & Future Work

Tradeoffs between ML & Responsible AI: Model Training Stage



Tradeoff conveyed between **Accuracy** during Model training stage and **Fairness**



Outline of this Presentation

- Background, Purpose, & Motivation
- Conceptual Modeling
  - Analyzing Tradeoffs in ML Design
  - Introducing the Conceptual Modeling Notation
  - Analyzing Tradeoffs in ML Design across Iterative Stages
- **Related Work**
- Conclusions & Future Work

Current Goal-Oriented Conceptual Modeling Techniques

Limitations of Current Approaches

- Cannot handle conflicting goals & priorities
- Ignore interrelationships & tradeoffs between goals
- Limited support for sensors, actuators, & nested iterative loops

Our Approach

- Adaptable to multiple perspectives & contexts
- First Goal-oriented conceptual modeling approach for Responsible AI (to our knowledge)

Computational Techniques for Responsible AI

Capabilities:

- Facilitate decision-support for data-driven apps

Lack critical reasoning capabilities:

- Tradeoff mechanisms
- Goal refinement processes
- Operationalization of technical ML and Responsible AI objectives (non-functional and functional requirements)

Checklists, Guidelines & Principles

Principle-Based Approaches: Challenges & Solution

- Universal approaches vs. project-specific needs
- Conflicting principles & limited relevance
- One-size-fits-all limitations

Goal Modeling: Contextual Solution

- Refine principles for specific contexts
- Flexible non-functional requirement (softgoals) representation
- Context-dependent approach

Outline of this Presentation

- Background, Purpose, & Motivation
- Conceptual Modeling
  - Analyzing Tradeoffs in ML Design
  - Introducing the Conceptual Modeling Notation
  - Analyzing Tradeoffs in ML Design across Iterative Stages
- Related Work
- **Conclusions & Future Work**

Conclusions & Ongoing Work

Research Contribution:

- Introduces 3 novel modeling constructs
- Presents innovative goal modeling methodology
- Aims to systematically design Responsible AI solutions

Ongoing Work:

- Actor interests (values) & conflicts (1) between individual actor interests and (2) among goals involving multiple actors
- Specific points in the ML process where these actors are engaged.
- Analyze conflicts in nested ML cycles & their impact on actor interests & priorities

Thank you