Principles of Knowledge Representation and Reasoning

Reasoning about Actual Causality

Bernhard Nebel, Felix Lindner, and Thorsten Engesser

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1 Responsibility and Blame

Motivating Example I: Responsibility

Example (Suzy and Billy throwing rocks again)

Suzy and Billy both throw rocks at a bottle, but Suzy's hits the bottle, and Billy's doesn't (although it would have hit had Suzy's not hit first). The bottle shatters.

- To give an argument for why Suzy is a cause for the bottle's shattering (and Billy is not), we had to make adaptions to our model of the situation (viz., witness $(\vec{W} = \{BH\}, \vec{w} = 0, \vec{x}' = 0)$ in modified HP).
- Intuitively, the more adaptions we have to make to prove s.th. a cause for an effect (the bigger $\vec{W}$), the less responsibility we are ready to attribute to the cause.

Motivating Example II: Responsibility

Example (Disjunctive Forest Fire again)

Forest fire breaks out in case there is lightning or a matched lit. As a matter of fact, there was lightning and a matched lit.

- Using but-for cause or the modified HP definition, neither L nor MD is a cause, but both L and MD are part of the cause $L \vee MD$.
- Intuitively, the bigger the cause, the less responsibility we are ready to attribute to the parts of the cause.

Definition: Responsibility

Definition (Responsibility)

The degree of responsibility of $X = x$ for φ in $(M, \vec{u})$, denoted $dr((M, \vec{u}), (X = x), \varphi)$, is

- **0** if $X = x$ is not part of a cause of φ in $(M, \vec{u})$;
- **1/k** if there exists a cause $\vec{X} = \vec{x}$ of φ and a witness $(\vec{W}, \vec{w}, \vec{x}')$ to $\vec{X} = \vec{x}$ to $\vec{X} = \vec{x}$ being a cause of φ in $(M, \vec{u})$ such that
  - (a) $X = x$ is part of $\vec{X} = \vec{x}$,
  - (b) $|\vec{W}| + |\vec{X}| = k$, and
  - (c) k is minimal, in that there is no cause $\vec{X}_1 = \vec{x}_1$ for φ in $(M, \vec{u})$ and witness $(\vec{W}', \vec{w}', \vec{x}_1')$ to being a cause of φ in $(M, \vec{u})$ that includes $X = x$ with $|\vec{W}'| + |\vec{X}_1'| < k$.

Application: Rock Throwing

- Rock Throwing, $(M, (1, 1))$
  - But-For Cause: Both $ST = 1, BT = 1$ are part of the cause $ST = 1 \vee BT = 1$.
    - $dr((M, (1, 1)), (ST = 1), (BS = 1)) = \frac{1}{|\emptyset| + |\{ST=1, BS=1\}|} = 1/2$
    - $dr((M, (1, 1)), (BT = 1), (BS = 1)) = \frac{1}{|\emptyset| + |\{ST=1, BS=1\}|} = 1/2$
  - HP definitions: Only $ST = 1$ is a cause, but we have to make at least one change to the model to prove that.
    - $dr((M, (1, 1)), (ST = 1), (BS = 1)) = \frac{1}{|\{BH=0\}| + |\{ST=1\}|} = 1/2$
    - $dr((M, (1, 1)), (BT = 1), (BS = 1)) = 0$

Application: Disjunctive Forest Fire

- Disjunctive Forest Fire, $(M, (1, 1))$
  - But-for cause and modified HP definition: $L = 1, MD = 1$ are part of the cause $L = 1 \vee MD = 1$.
    - $dr((M, (1, 1)), (L = 1), (FF = 1)) = \frac{1}{|\emptyset| + |\{L=1, MD=1\}|} = 1/2$
    - $dr((M, (1, 1)), (MD = 1), (FF = 1)) = \frac{1}{|\emptyset| + |\{L=1, MD=1\}|} = 1/2$
  - original and updated HP definition: $L = 1$ and $MD = 1$ are seperate causes with witnesses $(\{MD\}, 0, 0)$ and $(\{L\}, 0, 0)$, respectively.
    - $dr((M, (1, 1)), (L = 1), (FF = 1)) = \frac{1}{|\{MD=0\}| + |\{L=1\}|} = 1/2$
    - $dr((M, (1, 1)), (MD = 1), (FF = 1)) = \frac{1}{|\{L=0\}| + |\{MD=1\}|} = 1/2$

Epistemic States: Motivation

- The attribution of blame (rather than responsibility) requires to take some agent's epistemic state before the actual situation occured into account.
- A responsible agent might have been uncertain about the actual outcome, and therefore deserves less blame.
- Two sources of uncertainty:
  - What values the (exogeneous) variables have, i.e., uncertainty about $\vec{u}$.
    - E.g., in the conjunctive Forest Fire, you consider possible that there was no lightning.
  - How the world works, i.e., uncertainty about M.
    - E.g., you consider possible that only lightnings cause fire but not lit matches.

Epistemic States: Definition

Definition (Epistemic State)

An agent's epistemic state is given by a pair $(\mathcal{K}, Pr)$, where $\mathcal{K}$ is a set of situations $(M, \vec{u})$, and Pr is a probability distribution over $\mathcal{K}$.

- Additional assumption: In case this definition is used to compute a degree of blame to $X = x$, it is assumed that $(M, \vec{u}) \models X = x$ for all $(M, \vec{u}) \in \mathcal{K}$ holds.
- Justifications for the assumption: If we ask for the degree of blame to $X = x$, we take the occurence of $X = x$ as given.

Definition: Blame

Definition (Blame)

The degree of blame of $X = x$ for φ relative to epistemic state $(\mathcal{K}, Pr)$, denoted $db(\mathcal{K}, Pr, X = x, \varphi)$ is

$$\sum_{(M,\vec{u}) \in \mathcal{K}} dr((M, \vec{u}), X = x, \varphi) Pr((M, \vec{u}))$$

Example: Disjunctive Forest Fire

- Consider the following situations:
  - $(M_1, (1,1))$: Fire breaks out if $L = 1$ or $MD = 1$, both of which hold.
  - $(M_2, (1,1))$: Fire breaks out if $L = 1$, which is the case. $MD = 1$ also holds, but does not cause fire.
- How much blame does the lit match deserve for $FF = 1$, if:
  - $\mathcal{K} = \{(M_1, (1,1))\}, Pr((M, \vec{u})) = 1$?
    - $1/2 \cdot 1 = 1/2$
  - $\mathcal{K} = \{(M_2, (1,1))\}, Pr((M, \vec{u})) = 1$?
    - $0 \cdot 1 = 0$
  - $\mathcal{K} = \{(M_1, (1,1)), (M_2, (1,1))\}, Pr((M, \vec{u})) = 1/2$?
    - $(1/2 \cdot 1/2) + (0 \cdot 1/2) = 1/4$

Note: Obliged Epistemic State

Example (Doctor)

A doctor treats a patient with a particular drug. The doctor does not know the drug would have a side effect which kills the patient.

- Especially in legal contexts, to determine blame, it can be more relevant to represent what should have been known (probably along with a representation of what actually was known).

Psychology of Counterfactual Reasoning

- Modeling various types of counterfactual thinking
  - Additive Upward: “If I started studying three days ago, instead of last night, I could have done better on my test.”
  - Subtractive Upward: “I should have never started drinking, then life would be much easier.”
  - Additive Downward: “If I went drinking last night as well, I would have done even worse.”
  - Subtractive Downward: “If I didn’t start studying two days ago, I would have done much worse.”

Possible Topics for Projects and Theses

- Models of Relief & Regret: Robot expresses relief and regret, understands human’s relief and regret. Tells human things could have turned out worse to make them feel better.
- Learning from failure: Robot understands when it did wrong and adapts behavior accordingly. Tells humans how they could have done better.
- Means and Side effects: In various ethical theories, this distinction is essential to moral permissibility judments.
- Explanations and Justifications
  - Justifications: Robot justifies a decision it has made, or tells human how to justify his/her decision.
  - Explanation: Takes the epistemic state of the addressee into account, viz., if I ask the robot to explain some phenomenon to me, I might not want it to tell me things I already know.
- Special topics: Thankworthiness, Volition & Blame

- In the counterfactual world, where no one of you attended the KR lecture, the lecture would not have been a success. Thanks for attending and

  Good luck for the exams :-)

2 Literature

Literature I


Pearl, J., Mackenzie, D.
The Book of WHY – The New Science of Cause and Effect,
Basic Books, 2018.


Halpern, J. Y.
Actual Causality,
MIT Press, 2016.