

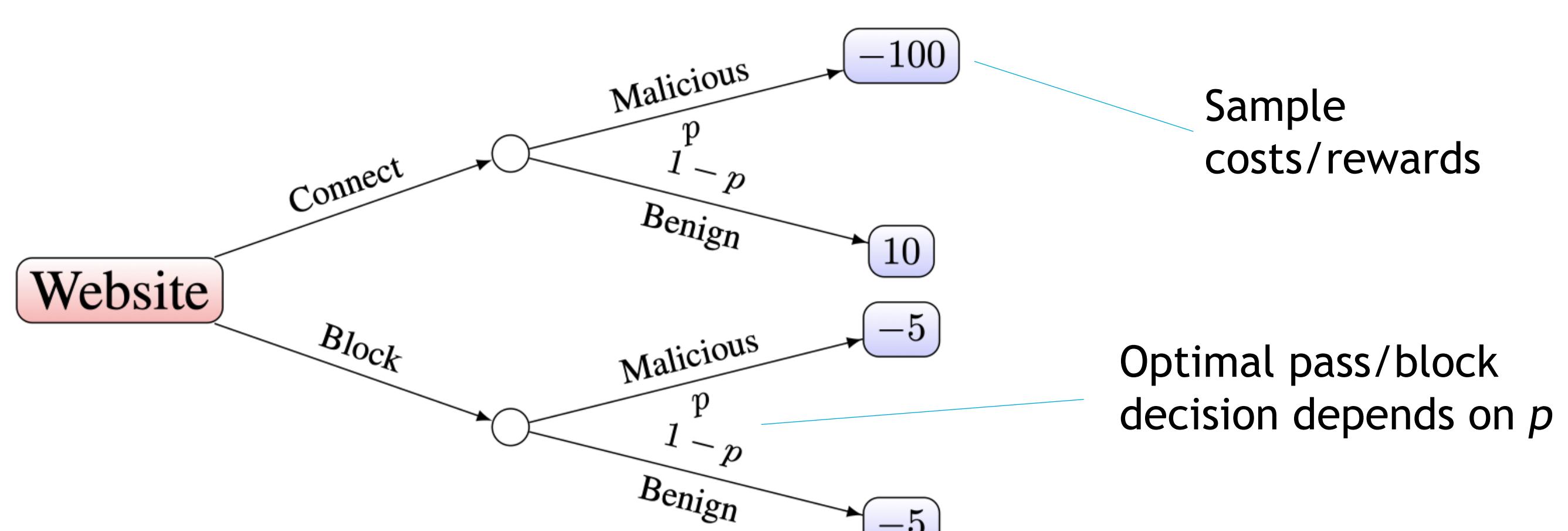


# Value of Uncertainty Reduction for Machine Learning Predictions

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## Introduction / Motivation

- We develop decision analytic tools to quantify and reduce machine learning (ML) prediction uncertainty as it pertains to a decision.



- Example: decide whether to block or connect to a website using an ML model to estimate  $p$ , the probability that the URL is malicious.

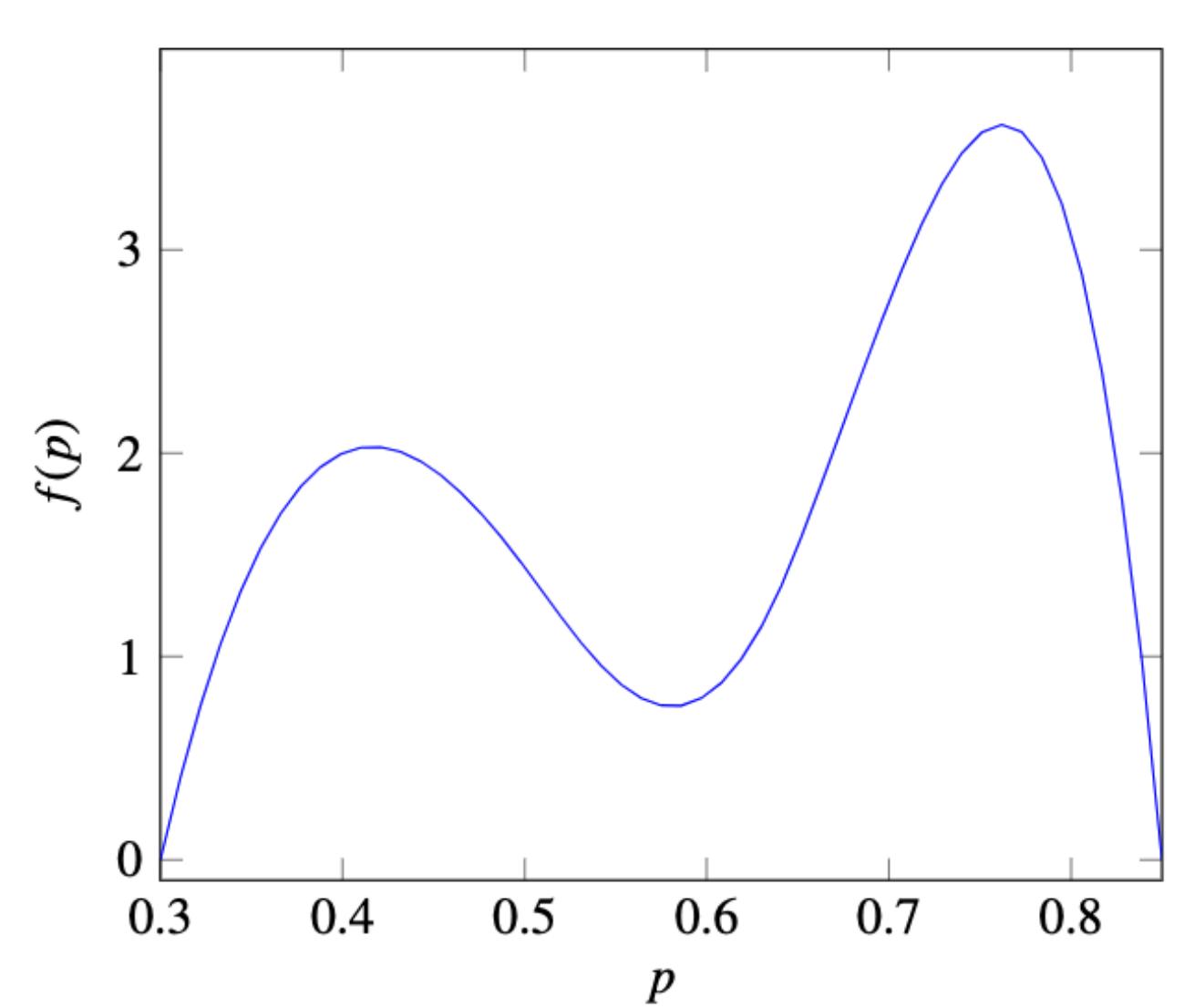
## Approach

### Value of Uncertainty Reduction

- Developed the **value of uncertainty reduction (VUR)**
  - The most a decision maker would be willing to pay to obtain information about the uncertain probability  $p$ .
- Initially estimate  $p$  using a lightweight model based only on the URL string
- Use VUR to decide whether to obtain more information about the website, such as HTML tags or other time-consuming queries.

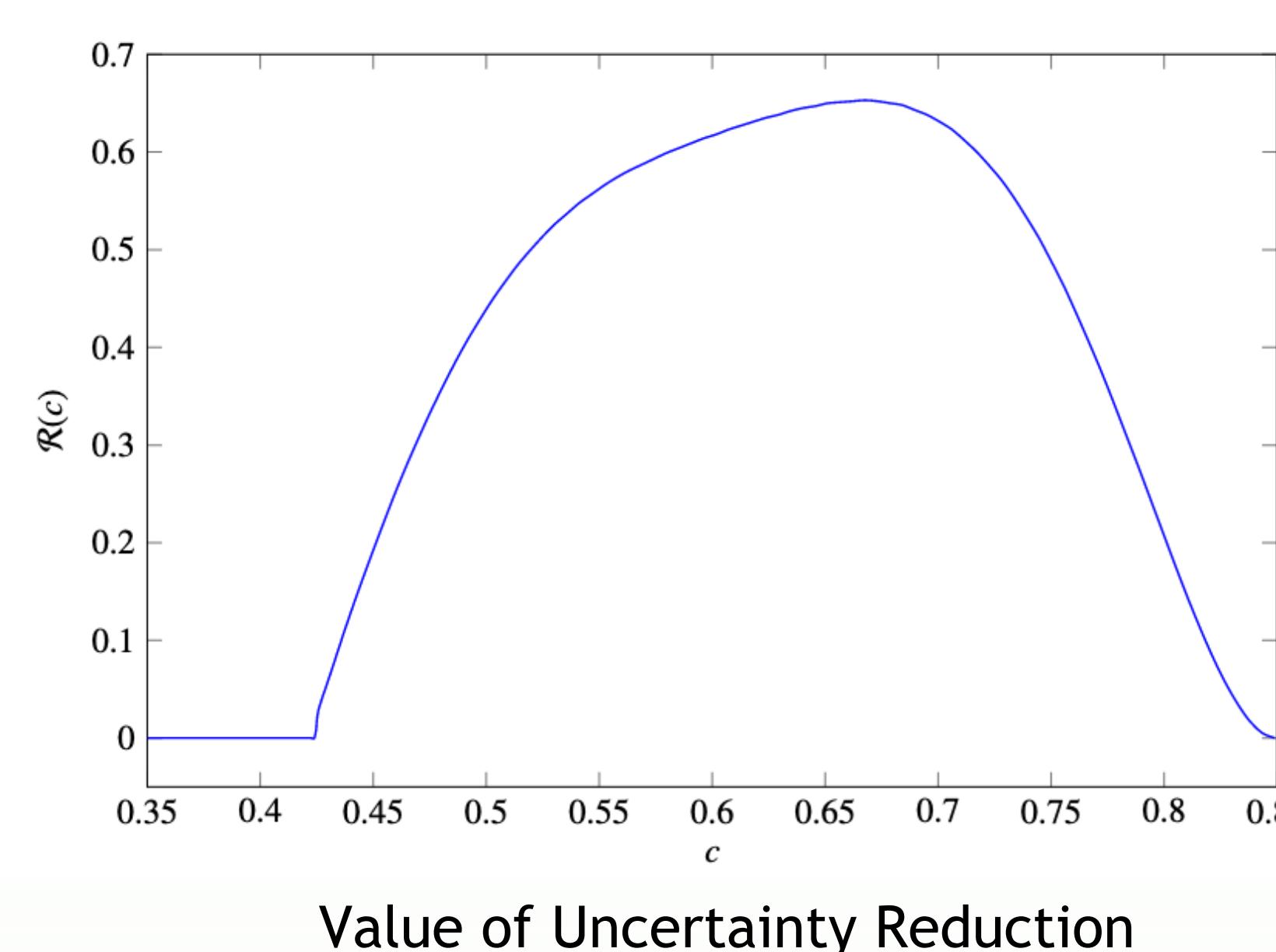
## Current Status / Results

- Example VUR calculation: suppose we have:
  - An initial ML estimate/distribution for  $p$
  - A more complex model that can tell us whether  $p \leq c$  for a given threshold value  $c$



Probability density function for  $p$

- We can calculate the value of uncertainty reduction  $R(c)$  as a function of the threshold value  $c$ .
- There can be value in reducing uncertainty even when there is an option to learn the true nature of the URL exactly.



## Challenges

- Significant conceptual and methodological gaps between the fields of machine learning and decision analysis.
- Actual costs/rewards are not always easy to define. One malicious URL may pose little more than an inconvenience, another may cost millions of dollars.

## Next Steps / Future Work

- Develop methods to directly train ML models to learn to make good decisions.
- Understand how to extend this work to handle outliers.
- Implement decision-tailored ML techniques in more complex (multi-class) numerical case studies.
- Develop techniques for problems with multi-objective optimization.