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Explainability-Driven Quality Assessment for Rule-Based Systems

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Motivation

Why Rule Quality and Explainability matter

- **Rules drive reasoning** in knowledge-based systems, but **errors, gaps, and biases** often go unnoticed.
- **Traditional validation** requires **manual checking** or **labor-intensive dataset labeling**.
- **Low-quality rules** compromise system **trustworthiness, fairness, and transparency**.
- **Explainability** offers a **human-centered, data-driven path** to **debug, refine, and improve** rules without retraining from scratch.

The Challenge: Ensuring Trustworthy Rule-Based Systems

Knowledge-Based Systems rely on **high-quality rules** for **reliable** and **trustworthy** reasoning.

Key Challenges:

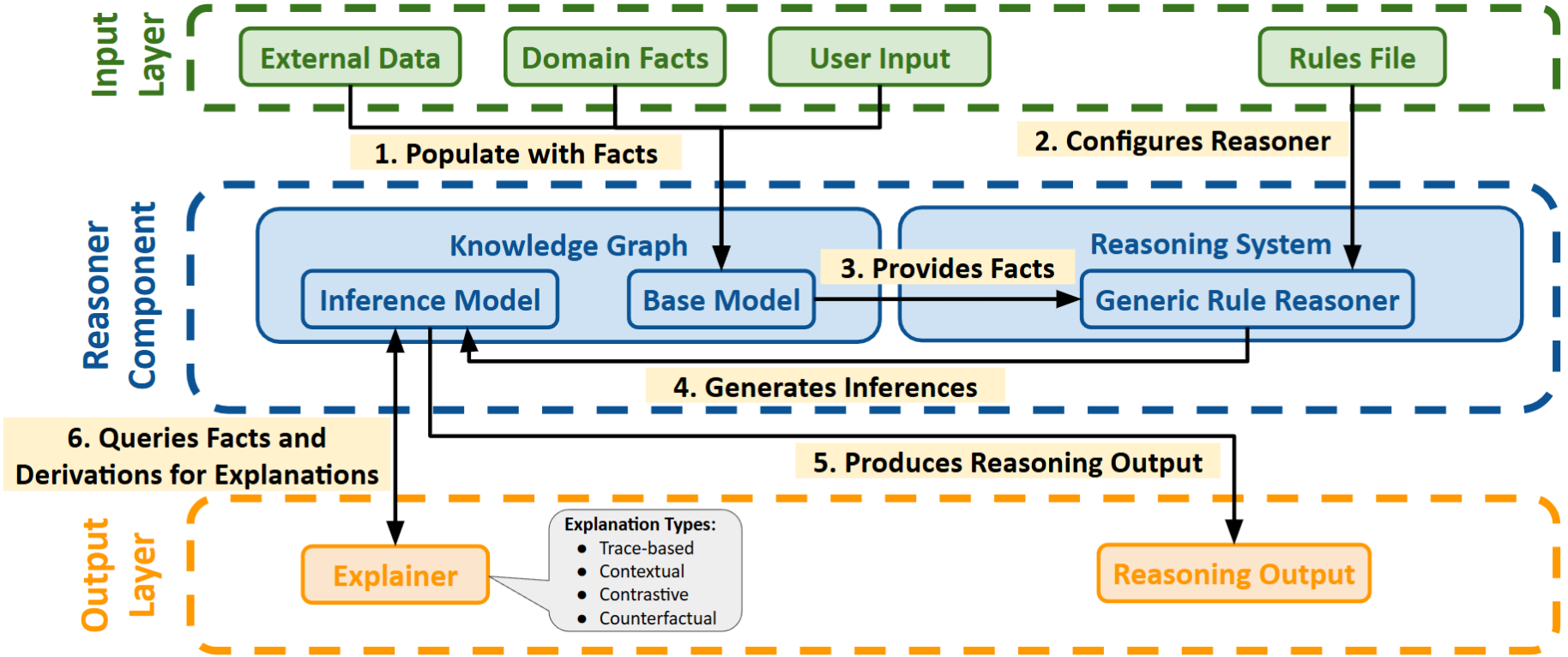
- Labor-intensive **data labeling** requirements
- **Incomplete** or **inaccurate** rules affecting outcomes

Our Strategy: Use **Explainability** to drive **quality assessment and refinement**.

Types of Explanations to Support Rule Quality:

- **Trace-Based**: Step-by-step rule derivations
- **Contextual**: Immediate rule and fact insights
- **Contrastive**: Comparative reasoning between outcomes
- **Counterfactual**: “What-if” scenarios to suggest changes

Our Solution Architecture



Use Case: Loan Eligibility Reasoning

Scenario: Assess loan eligibility based on:

- Credit Score
- Debt-to-Income (DTI) Ratio

Applicants:

- 👦 **Alex**: Credit Score 680, DTI 0.40 → ❌ *Not Eligible (High DTI)*
- 👦👦 **Beth**: Credit Score 605, DTI 0.30 → ❌ *Not Eligible (Low Credit Score)*
- 👦💼 **Charlie**: Credit Score 700, DTI 0.20 → ✅ *Eligible*

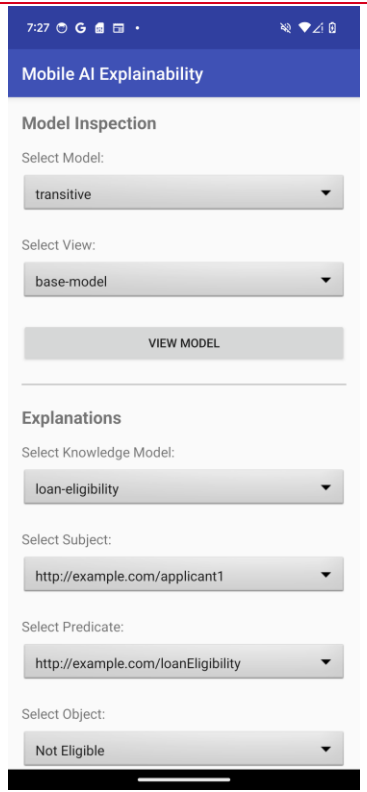
Goal:

- Use explanations to understand and debug eligibility decisions.

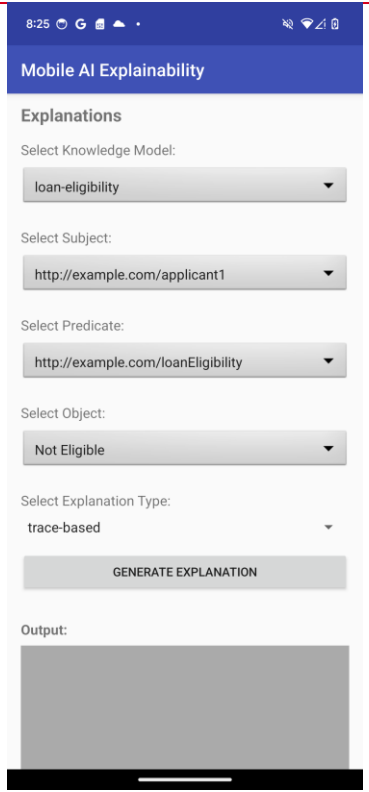
Four Types of Explanations for Rule Quality Assessment

Type	What It Shows	Why It Helps
🔍 **Trace-Based**	Full derivation chain	Debug unexpected rule interactions
🚦 **Contextual**	Immediate rule and facts	Quickly validate local rule behavior
⚖️ **Contrastive**	Differences between two cases	Refine thresholds, detect unfairness
🔄 **Counterfactual**	Minimal changes to flip outcome	Suggest actionable improvements

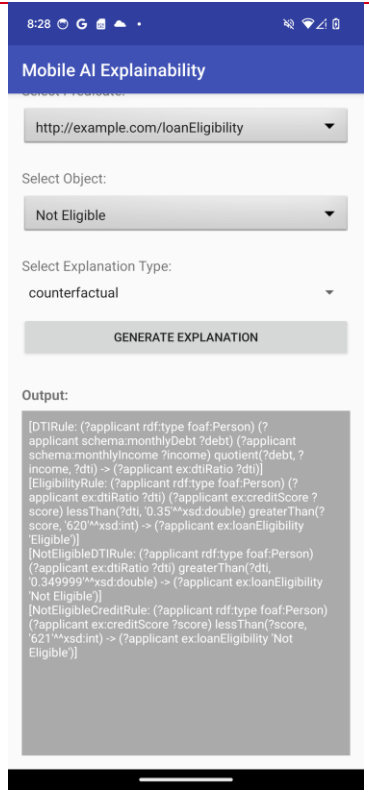
Demo – Scenario Setup



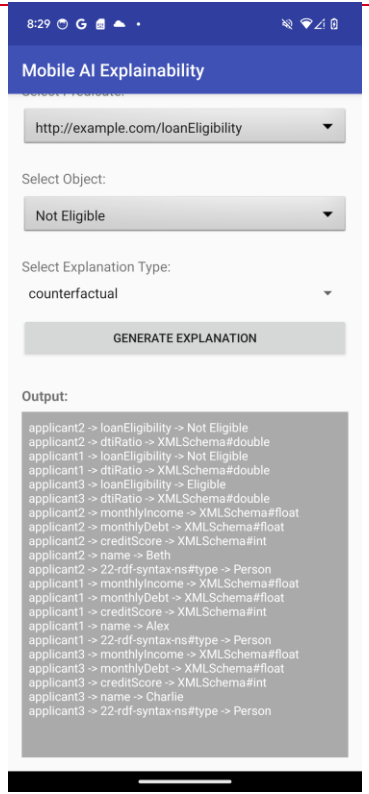
Model Inspection Pickers



Explanation Input Pickers

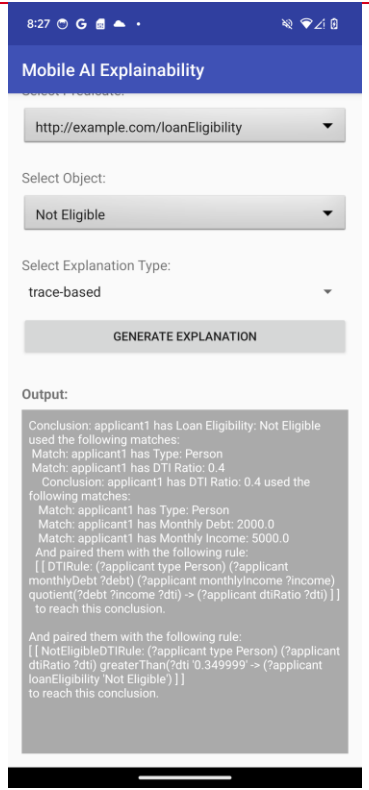


Loan Eligibility Model Rules

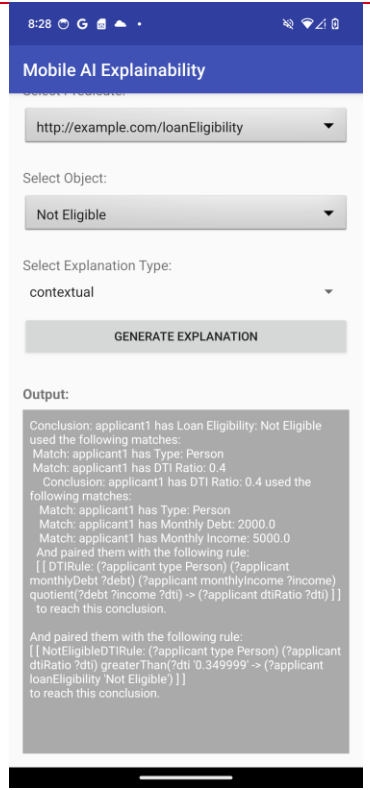


Inference Model

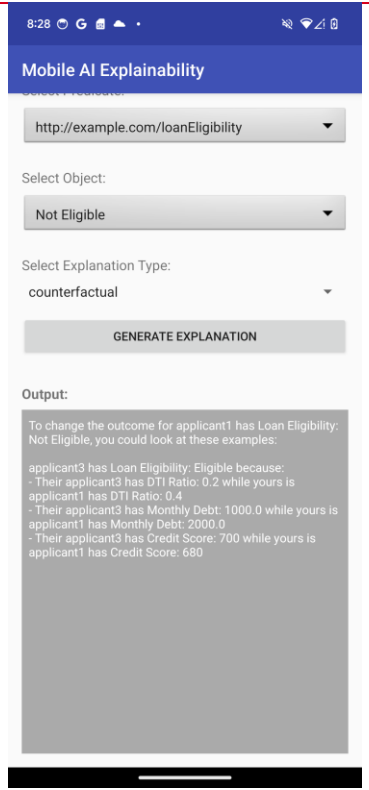
Demo – Different Explanations



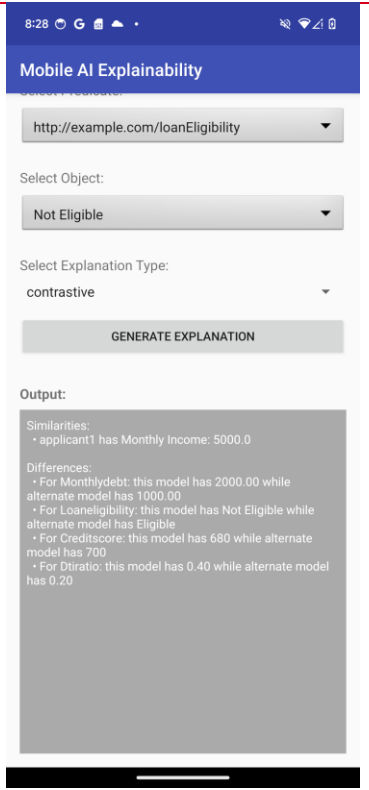
Trace-Based Explanation



Contextual Explanation



Contrastive Explanation



Counterfactual Explanation

Conclusion

- **Rule quality** is critical for **trustworthy knowledge-based systems**.
- **Explainability** transforms rule validation from manual checking to **systematic, human-centered refinement**.
- Our framework supports **trace-based, contextual, contrastive,** and **counterfactual** explanations.
- Integrated into the **MIT App Inventor Punya** platform for practical, lightweight reasoning.

- **Future Directions**:
  - Improved **UI/UX** for explanation readability
  - **User studies** to evaluate trust, usability, and impact

More Information

- Paper: https://arxiv.org/abs/2502.01253
- Code: https://github.com/brains-group/androidReasoningPunya

- MIT App Inventor: https://appinventor.mit.edu
- Punya Project: https://punya.mit.edu

Email: senevo@rpi.edu
Website: https://oshani.info

Questions?

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