Reinforcement Learning for Market Stability in Wildfire Insurance

2. **Short summary**. What problem statement or research question that your project aims to address? Why is it interesting?

The insurance market in disaster-prone areas such as the wildfire WUI often becomes unstable because the government premium cap K, the insurer entry decision and premium setting P, and the homeowner purchase decision are tightly interconnected. The main research question is: How can RL be used to dynamically design and adjust premium caps K and insurance premiums P that stabilize the market while balancing insurer profit and homeowner risk reduction? This research is interesting because it involves a three-party decision-making problem that connects government, industry, and individuals. Simple optimization methods are not sufficient due to the complex interdependence of decisions. In addition, the uncertainty of fire probability q and potential loss L requires adaptive policy exploration through RL.

3. **Objectives**. Outline the goals you aim to achieve.

The study aims to maximize government objectives by enhancing market stability and preventing insurer exit while ensuring that enough homeowners participate. It seeks to allow insurers to maximize expected profit by setting premiums that balance expected payouts with operational costs. It also aims to help homeowners minimize both fire losses and premium costs while still accounting for the psychological utility X of coverage. The integrated goal is to apply multi-agent reinforcement learning to adjust premium caps K and premiums P to learn policies that converge to Pareto-efficient outcomes.

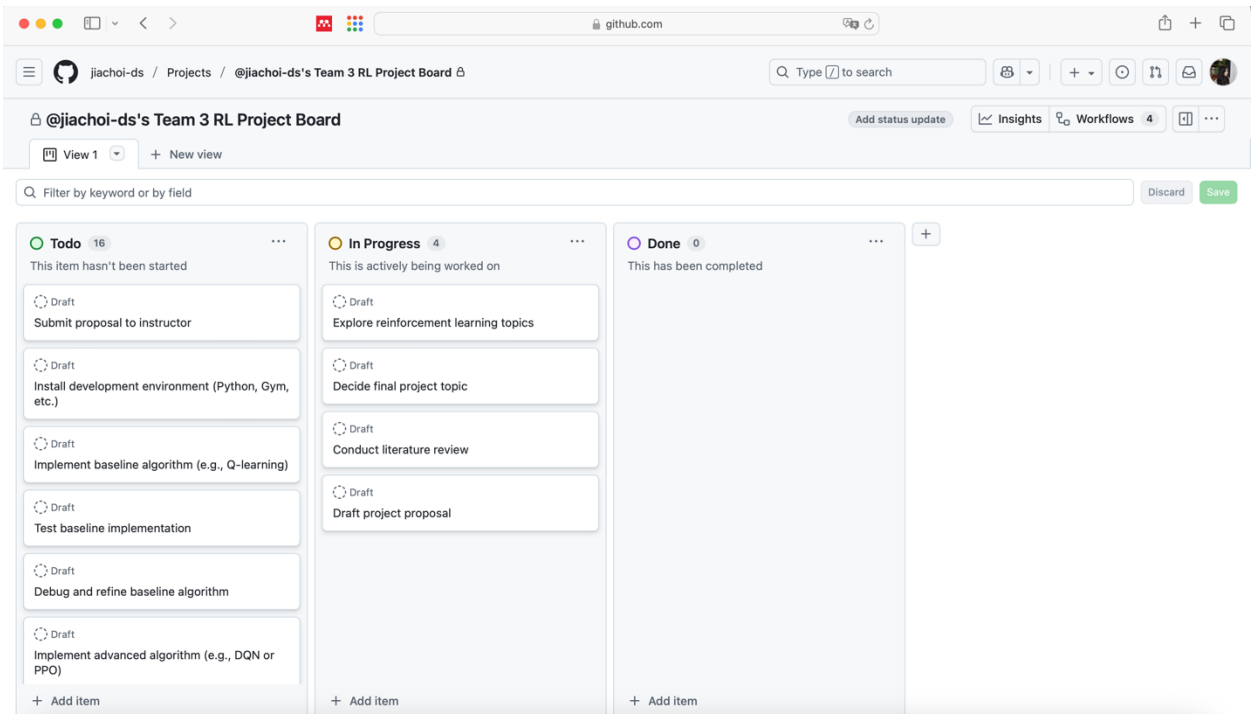
4. **Methodology**. What RL techniques, models, or algorithms you plan to use? How do you plan to improve or modify such implementations? You don't have to have an exact answer at this point, but you should have a general sense of how you will approach the problem you are working on.
- Among of DQN, A2C, PPO
- model : Depth: 128*3, Activation: ReLU
- improvement plan: define specific state and action space (avoid redundecy), design reasonable state transition, LQR closet reward function

5. **Evaluation**. How will you evaluate your results? Qualitatively, what kind of results do you expect (e.g. plots or figures)? Quantitatively, what kind of analysis will you use to evaluate and/or compare your results (e.g. what performance metrics or statistical tests)?

The evaluation will focus on both qualitative and quantitative outcomes. Qualitative results include learning curves of agent rewards, plots showing the evolution of premium caps and premiums across episodes, and observed market outcomes such as insurer entry rate, homeowner coverage rate, and frequency of insurer exit. Quantitative results are based on government stability measured by the variance of insurer participation, insurer performance measured by positive expected profit with low variance, and homeowner welfare measured by average loss avoided and overall coverage rate. Joint outcomes will be compared on a Pareto frontier of profit, coverage, and risk. Statistical evaluation will include paired t-tests or Wilcoxon tests that compare MARL results against baseline scenarios such as static cap policies.

6. **Environment**. What environment(s) do you plan to use?
model : MDP Tuple : MDP(S,A,R,P, ρ, γ)
Where,
S={Premium_{i, k}} where 0 < i <=3, 0 < k <=2
A = {K} where K is continuous value
R = LQR form using utility function (designed) ->
P = deterministic env.
ρ = pseudo random
γ = 0.99

7. Github (https://github.com/users/jiachoi-ds/projects/1)



8. **References**. Include a list of the relevant literature and resources you plan to use.

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