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Achieving Fairness with Intelligent Co Agents

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***Abstract:** Fairness in resource allocation is a important problem that has many real life consequences. Althoughmany algorithms that try to achieve envy free allocation, proportionality or min max share were proposed that tries to encapsulate fairness this does not suffice because it was inherently assumed that agents are not intelligent and there is uniformity in treatment. This is vastly different from real life where there are many scenarios where agents would actively try to sabotage or reduce the allocation given to their adversaries. Therefore all agents must not be treated the same way. As seen in economics cartels are where certain players collaborate and try to maximize their interest by undermining competition. This could lead to dangerous consequences and unfair means as seen withreal life examples of apple or google undermining competition by monopoly as explained clearly in (Das, Dhamal, Ghalme, Jain, & Gujar, 2022 [1])*

***Keywords:** Economics, Undermining Competition, Life Consequences*

I. INTRODUCTION

Algorithms that exist for Divisible and indivisible fair resource allocation for a set of agents have the problem with assuming that all agents are uniform that is fairness as an idea is applicable to each agent irrespective of identity. But clearly this notation is flawed when dealing with big agents with huge valuation functions or the capacity to collaborate and create oligopolies. Hence in this paper we are introducing new notion of fairness called Collaboration independent fairness and Interference independent fairness that exclusively deals with oligopolies. This definition is also backed by philosophical framework of promoting fairness, punishing unfairness and reciprocity. But one must be careful with incorporating it completely as reciprocity could also lead to cartel formation between similar agents. So achieving fairness therefore has to be entrusted to a centralized trusted evaluator called Judge which itself should not be biased. We have proposed algorithms on how judge tries to maintain fairness and maximize the incentive for agents to act fair. These ideas were inspiredfrom tales of robinhood

II. BACKGROUND AND DEFINITIONS

Fair resource allocation is a problem where resources that can be mapped are to be distributed toset of agents while achieving fairness quantification's

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A. Envy Free Allocation

For a set of n agents, an allocation $A = (A_1, A_2, \ldots, A_n)$ is called envy free if $\forall i, j,\ v_i(A_i) \geq v_i(A_j)$ where v corresponds to valuation functions

B. Proportional Allocation

For a set of n agents, an allocation $A = (A_1, A_2, \ldots, A_n)$ is called proportional if $\forall i$,

$$v_i(A_i) \geq \frac{1}{n}$$

C. Equitable Allocation

For a set of n agents, an allocation $A = (A_1, A_2, \ldots, A_n)$ is called equitable if $\forall i, \forall j$

$$v_i(A_i) = v_j(A_j)$$

D. Joint Valuation Function

Joint valuation function between two agents i and j is defined as the total observed valuation when two intelligent agents are interacting with each other over allocation $A_i \cup A_j$

E. Collab Independent Fairness

For a tuple of agents A_i and A_j if the joint valuation function does not increase or decrease when two agents collaborate then it is called collab independent fairness. In more simple terms their joint valuation should be equal to sum of their individual valuations. this could also be explored in terms of multi agent systems as discussed in (Jiang & Lu, 2019 [2])

$$v_{ij}(i \ \& \ j) = v_i(A_i) + v_j(A_j)$$

F. Judge

An external evaluator that tries to ensure collab fairness and interference fairness by changingcollusion coefficient

G. Collusion Coefficient

A coefficient associated with each agent that describes its collusionary tendencies. If there is high collusion coefficient then agent is interfering in other agent's valuation functions

H. Interference Independent Fairness

For a set of n agents an agent is said to be achieving Interference independent fairness if

$$c_i \leq 0.1$$

where c_i is collusion coefficient that is decided by Judge. If all agents follow the condition then the allocation is said to have complete interference independent fairness.

III. PROBLEM STATEMENT

In a fair resource allocation problem given set of agents A_1, A_2...A_n that are trying to share resources with specific valuation functions. And a Cartel set $S \in \{A_1, A_2, . . . , A_n\}$ that is adverse to aparticular agent A_i.Achieve an allocation that has maximum possible collab independent fairness and interference independent fairness and tries to ensure proportional allocation for non collab agents

IV. METHODOLOGY

Since the main goal of the problem to achieve fairness for non collab agents (agents that have col- lision coefficient less than a certain threshold) It involves with allocating the best possible initial allocation using dubins spainer algorithm which tries to ensure proportionality for most of the agents

$P_0 = (A_1, A_2, . . . , A_n)$

Now after finding the initial allocation Judge will check the joint valuation function and if forany agents i j

$v_{ij}(i \ \& \ j) > v_i(A_i) + v_j(A_j)$

then the judge sense this and give penalties in the form of increasing their collusion coefficients c_i(initially all of them are zero) and all other cases the agents either remain indifferent or hate each other Now we can do this with the help of correlation matrix C

C11 C12 C13 C21 C22 C23 C31 C32 C33

Where Cij represents correlation or collusion between Agent i and j. This can be measured by joint valuation function

The judge can give collusion coefficients from machine learning model

$y = w^T x + b$ (1)

$x = v_{ij}(A_{ij})$ (2)

y = judge coefficient (3)

Now after handing out the collusion coefficients for all the agents then agents with collusion above certain threshold will be selected and put into an list. Sort the list in decreasing order then according to requirement (no of agents that are lacking proportanity) a set within this list with thelarge collusion coefficients are taken and its resources are pooled into allocation pool and reallocatedaccordingly

Selected collusion agents set

$S_c = \{A_{i1}, A_{i2}, . . . , A_{ik}\}$

Since agents are intelligent this will serve simultaneously as a loss function and justice. After reallocating the resources then judge will decrease the collusion coefficient and remove the agent from the list Now how much of the resources should be deallocated from the collusion agents is decided by judge based on collusion coefficients. Judge takes an agent allocation and deallocates some resourcesin this case x_i

$J : A_i \to A_i - x_i$

Allocation from allocation pool $A_p = x_i$ . . . . . . will be auctioned according to the valuation functions and agent with lowest valuation function will be given(among all the other agents that showed interest in the particular allocation).We have provided an algorithm that deals with collusion in the next section. Note that general ml algorithms themselves collude becuase of objective funcitonas explored in (Schwalbe, 2019 [4][8][9])

V. DISCUSSION

Why does this work? the given system works because fundamentally we have incorporated achieving fairness as goal. Penalty system instead of rewards is done because we cant reduce oligopoly with rewards .And judge should also ensure that the system is rehabilitating instead of punishment which occurs because an colluder could also become poor agent therefore could have a chance of achieving proportional allocation. There is also an philosophical concept discussed in detail at (Michelson, 2022 [3][5][6][7]) included known as golden rule which is incorporated here to achieve fairness

Algorithm 1

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Initialize P0: P0 = {A1, A2, . . . , An} (Dubin's snapier)
Define J: J : {CM → {C1, C2, . . . , Cn}}
(Judge taking collusion matrix and giving collusion coef-ficients)
Choose Sc: Sc = (Ai1 , Ai2 , . . . , Aik )(Top Colluder set)
Transform using J: J : Ai → Ai − x(Judge deallocation)
Now collect all those x from each allocation and pool them into AP set
Poor agent set(that acted fairly and has not achieved proportionality) PA set
for each i in AP do
    for each j on PA do
        if Vj(i) achieves proportanility and is poorest agent then
            Allocate i to j
            Remove i from AP
            Remove j from PA
        end if
    end for
end for
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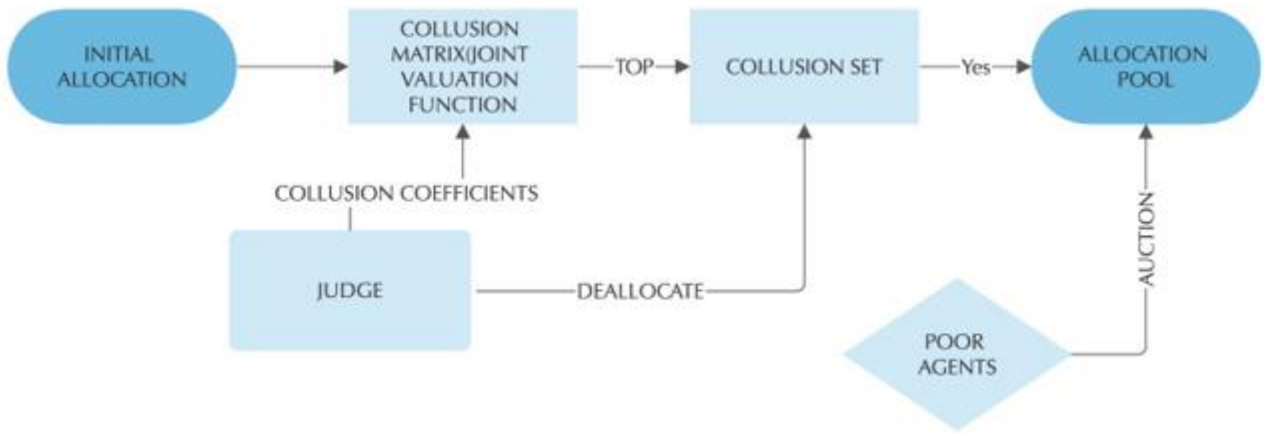

Figure 1: Flow Chart

VI. RELEVANCE

We can see real life relevance to this problem as there are many examples where powerful agents try to interfere to enhance their interests. An real life example would be a big company like apple could potentially stop running its apps on a small android phone therefore forcing users to buy apple phones. An example of oligopoly are apple and windows colluding and reducing prices so low(they can afford loss in short term)that other companies go bankrupt. So not having fairness could be catastrophic in these cases

VII. CONCLUSION AND FUTURE PROSPECTS

In this usecase we have explored the fair resource allocation of intelligent agents with possible chance of oligopoly which can be unfair and therefore we have introduced new notion of fairness to help creating a framework for minimizing collaboration. Although judge is used to maintain fairness it could also introduce its own biases and in some cases harsher penalties could potentially be unfair. For future the algorithm can be improved so that instead of just proportionality envy freeness and equitably could also be followed.

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AUTHOR PROFILE

Katha Rohan Reddy is currently studying my final year in IIITh. I am currently working on fairness and privacy. I have expertise in machine learning, web development and cryptography My hobbies are swimming, reading books etc. I am planning to pursue my masters' studies after i graduate I have published an article regarding fairness in ai where i discussed introducing a new metric of fairness when intelligent agents were involved. We have studied different interactions between agents and applied proper fairness metrics to evaluate the decision making.