

University of Ruse "Angel Kanchev" MULTIAGENT SYSTEM WITH ARTIFICIAL INTELLIGENCE

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LECTURE 10

Multiagent Systems Coalitions

- 1. Coalitions
- 2. Shapley
- 3. Coalition Games



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Forming Coalitions

Coalitional games model scenarios where agents can benefit by cooperating. Sandholm (et. al., 1999) identified the following stages:

Coalitional Structure Generation

Deciding in principle who will work together. It asks the basic question: Which coalition should I join? The result: partitions agents into disjoint coalitions. The overall partition is a coalition structure.

Solving the optimization problem of each coalition Deciding how to work together, and how to solve the "joint" problem" of a coalition. It also involves finding how to maximise the utility of the coalition itself, and typically involves joint



planning etc.

Dividing the benefits

Deciding "who gets what" in the payoff. Coalition members cannot ignore each other's preferences, because members can defect: ... if you try to give me a bad payoff, I can always walk away... We might want to consider issues such as fairness of the distribution.







Characteristic Function Games

The objective is to connect a coalition that the agent cannot question to - this includes also calculating the characteristic function for different games.

Each coalition has its own payoff value, defined by the function

v(C) = k then the coalition will get the payoff k if they cooperate

on some task

Sandholm (1999) proposed:

- ➢ If the game is superadditive:
 - > if v(U) + v(U) < v(UUV)
 - The coalition that maximises social welfare is the Grand Coalition



If the game is subadditive:

- > if v(U) + v(U) > v(UUV)
- The coalitions that maximis social welfare are singletons
- However as some games are neither subadditive or superadditive:
 - the characteristic function value calculations need to be determined for each of the possible coalitions!
 - > This is exponentially complex





Characteristic Function Games

- Accepting that we know the characteristic work and the payoff > Where "efficient" means: vector, what consolidation ought to an agent join?
- \succ An outcome x for a coalition C in game (Ag, v) is a vector of payoffs to members of C, such
- \succ that x = (x1, ..., xk) which represents an efficient distribution of payoff to members of Ag



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- \succ Example: if $v(\{1, 2\}) = 15$, then possible outcomes are: $\langle 15, 0 \rangle$, (14,1), (13,2) ... (1,14), (0,15)
- \succ Thus, the agent should only join a coalition C which is:
 - *Feasible*: the coalition C really could obtain some payoff than an agent could not object to; and
 - *Efficient*: all of the payoff is allocated





Characteristic Function Games

- In any case, there may be numerous coalitions
- Each contains a diverse characteristic function
- > Operators lean toward coalitions that are as beneficial as possible
- Hence a consolidation will as it were shape in the event that all the individuals lean toward to be in it
- I.e. they don't imperfection to a more ideal fusion



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> Therefore:

- "which consolidation ought to I join?" can be decreased to "is the amalgamation stable?"
 - Is it levelheaded for all individuals of fusion C to remain with C, or seem they advantage by abandoning from it?
 - There's no point in me joining a amalgamation with you, unless you need to create one with me, and bad habit versa





Stability

- The concept of stability can be reduced to the concept of the core.
 - Stability is a necessary but not sufficient condition for coalition formation
 - i.e. unstable coalitions will never form, but stable coalitions are not guaranteed to form
- The core of a coalitional game is the set of feasible payoff distributions to coalition members that no sub-coalition can reasonably object to
 - Intuitively, a coalition C objects to an outcome if there is some other outcome that makes all of them strictly better off



- The idea is that an outcome will not happen if someone objects to it!
 - i.e. if the core is empty, then no coalition could form





Sharing the Benefits of Cooperation

The Shapley value is best known attempt to define how to divide benefits of cooperation fairly.

- It does this by taking into account how much an agent contributes.
- The Shapley value of agent i is the average amount that i is expected to contribute to a coalition.
- The Shapley value is one that satisfies the axioms opposite!

Symmetry

Agents that make the same contribution should get the same payoff, i.e. the amount an agent gets should only depend on their contribution.

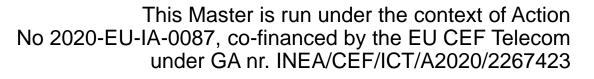
Dummy Player

These are agents that never have any synergy with any coalition, and thus only get what they can earn on their own.



Additivity

If two games are combined, the value an agent gets should be the sum of the values it gets in the individual games.









Shapley Axioms: Symmetry

> Agents that make the same contribution should get the same

payoff

- The amount an agent gets should only depend on their contribution
- Agents i and j are interchangeable if their marginal contribution are the same for each coalition
- > The symmetry axiom states:
- If i and j are interchangeable, then their Shapley value is equal



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Shapley Axioms: Dummy Player

- > Agents that never have any synergy with any coalition, and thus only get what they can earn on their own.
- > An agent is a dummy player if he/she only adds to a coalition what it could get on its own









Shapley Axioms: Additivity

- If two games are combined, the value an agent gets should be the sum of the values it gets in the individual games
- > I.e. an agent doesn't gain or loose by playing more than once







Shapley value

- Recall that we stated:
- The Shapley value for an agent is based on the marginal contribution of that agent to a coalition (for all permutations of coalitions)
- > The marginal contribution can be dependent on the order in which an agent joins a coalition
- > This is because an agent may have a larger contribution if it is the first to join, than if it is the last!
- \succ For example, if Ag = {1,2,3} then the set of all possible orderings, is given as {(1,2,3), (1,3,2), (2,1,3), (2,3,1), (3,1,2), (3,2,1)



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Coalition Games

Representing Coalitional Games

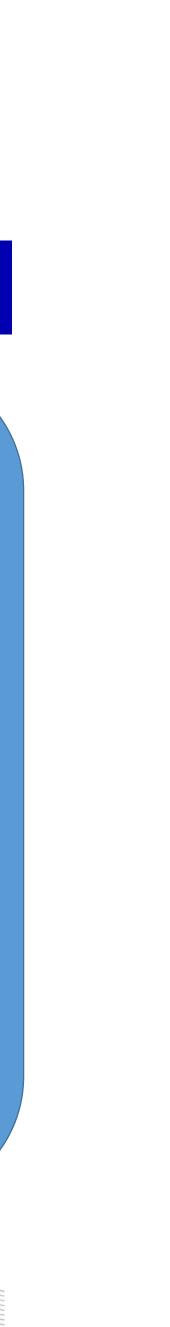
- It is important for an agent to know if the core of a coalition is non-empty
- Problem: a naive, obvious representation of a coalitional game is exponential in the size of Ag.
- > Now such a representation is:
 - utterly infeasible in practice; and
 - so large that it renders comparisons to this input size meaningless
- > An n-player game consists of 2n-1 coalitions
 - e.g. a 100-player game would require 1.2 x 1030 lines



Co-financed by the European Union Connecting Europe Facility % Representation of a Simple % Characteristic Function Game

% List of Agents 1,2,3 % Characteristic Function 1 = 5 2 = 5 3 = 5 1,2 = 10 1,3 = 10 2,3 = 10 1,2,3 = 25







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- 4. T. Sandholm, K. Larson, M. Anderson, O. Shehory and F. Tohme, "Coalition structure generation with worst case guarantees", Artifi. Intell., vol. 10, pp. 209-238, July 1999.



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