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Right? Now, basically, we can divide the games into different types. For example, sequential moves meaning you move first and then some other movement and then some other move. All right? And then there's also be simultaneous move, all the people move together, right? So when all the people move together, the result would be even worse for everyone, right? So this is very likely. Then there's also zero sum amount, zero sum game. Single player interested play game, perfect information and imperfect information game, and also cooperative and non cooperative games.

Now, sequential game and a sequential group and simultaneous group. Right? Now, sequential move game, this one is a characterized by extensive form game. All we call it combinatorial games here. What is this? It's basically, for example, you play chess or a goal, right? You move first. All right. And after that, your proponent rules, then you move again. Right? So basically, based on that, you can draw a game tree, right? From starting point, you move, you do different choices. You can go to different branches, right? And then for each of them, the opponent can move. Again. There are multiple branches, right? So basically, we use the entry to describe how the game will go. Right? This is about the extensive home game. And then the normal home game, you assume people simultaneously. But simultaneously, it also is divided into two categories. One is 1 by 1 group, the others at the same time. We already talked about that if you move at the same time, for example, you have two players, right? And then they have multiple strategies.

Now they're doing like this. And then this person thinks, given this versus twice, I do another thing, especially, right? And then this person says, given its opponents current choice, I do nothing is better. But when they both move to another thing, it could be even worse for both of them, right? That's very likely. So if you allow the so called at the same time, you then the result of the evil worse. In that case, one by one could be could be better. But still, even if one by one, when there is no equilibrium, you still cannot achieve an output outcome. But this is some previous little game. Usually we use the so called payoff matrix to describe the game. Not a tree, because for sequential game, you use a game tree or extensive one game tree structure to describe. But here we use a payoff matrix describe. We will use one example to illustrate this payoff matrix.

For example, this is a role player 301. This is a column player vector. Then role player has two strategies. A and b probably also have two strategy a and b but this statement is different from this a this be also different from this ok these two strategies become compared to these two belong to play on ok now I want to see the 01. If it chooses strategy, then player two choose eight, then player one will get p one, player two will get p two. You see that in the entry of every cell of the matrix, you have two components, one component. The first component is the game for player one. Second component is the game for player two.

Now, if you specify all these numbers, 123456788 numbers, you decided, and then the game is decided, okay.

Now, if this is a zero sum game, they don't need to even give a number. You just give four numbers, these 41 given, and then these people would just feel negative of the one. Because it's zero sum zero sum game. We need four numbers. We'll use a very famous prisoners dilemma to explain this zero sum game, but this is not zero sum. This is a normal game. It's not zero sum game. So prisons dilemma is the following.

Now, i'm sorry, it's too far away this now. So everyone has the two choices. Basically, these are two prisoners. Everyone has two choices, either blame the other person, or keep a secret. So I do not blame him, right? It's not guilty. Now we see in this game, if both of them keep secret, it's okay, and do not blame the other. This muscle says that do not blame the other. Then there is sentence. So sentence they will be sentenced to 1 years jail, 1 years in prison. Okay, so this 1 year is actually very good. Why? Because you see all the other cells, there either 10 years or 20 years, right? It's very long. So 1 month could be the best benefit, best outcome for these two people.

Now, if both of them blame each other, say they were prisoner, this one says he's guilty, and this also says he is guilty, and then both of them will be sentenced to 10 years in jail. All right, in prison. Now, if one of them do not blame the other person and the other person blame this person, then the one who don't blame will be sentenced to 20 years. The other one will be released immediately. This is a tricky .. If you keep a secret, but your partner does not keep a secret, say you are guilty, then you will be sentenced 20 years, right? And then the partners go. Now let's see whether we can achieve some equilibrium in this game.

Now we know this 11 is the best outcome, right? 11 is the best outcome for all people altogether, because the total number of years is only two, right? It's very good, but this one is not stable. Why? Because if you are at the stages, then player two says I changed my strategy from don't blame to blame. Then ii will be released well, right away. I okay, so then try to say, ii confess he's guilty. All right? And then he changed from 1 year to 0 year, right? It is about to leave, but then you suddenly realize no.

Now, if I don't blame my partner, I will be since 20 years. That's not good. Then I also change to blame. If I change the blame, my sentence, reduce from 20 to 1 to

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10. All

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right? Now, if you are at this status, , nobody will move in anymore. Ten ten is very stable, because no matter which one to change, the decision to know, don't blame, their sentence is increased to 20 years, right? So

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nobody will change.

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Now, the national equilibrium becomes ten ten, the first one. That's why it's called christmas dilemma, because if you go for the equilibrium, each of them will be sentenced to 10 years. But if you have a good coordination between them, they both keep secret. They will have this result 1 month, right?

That's a dilemma when people do not know what to do, right? Whether I confess or I play the other person or I do not. Right? So this is bad. Actually, in this lecture, we'll see many more dilemmas, but let's see. All right. There are some other games. For example, there's a chicken scheme. The chicken scheme was a non zero sum game. This is a a non zero sum, because you see this cell, - 1,000, - 1,000, you add up to - 2,000 is 2 to a small, right? It's very small value.

Now, for chicken, for the chickens game, we also call it hawk dog game. So in this game, there is a very special nature. The nature is the people the player can choose to fight or do not fight means what means a dodge here? Iii do

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not fight you

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now for this game, you see, if both of them fight, and then both of them will be hurt a lot. Okay? If this could be imagined from the hawk, right? If two hawks fight each other, then a lot of feathers will drop from their wings. So that's unavoidable. Now, if both of them dodge, they get zero, both of them are zero. Now, again, the interesting thing happens when one of the fights, the other one dodge, and then the one who fights gain

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a bit,

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and then the one to dodge loses a bit. Okay? Why? Because it's about the ego right? Ok so if I fight, you want do not fight back with me, then somehow your ego is lost a bit, right?

So basically it's about the self section. Right? In this game. What is the national program? It's

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probably be the host. Also, one goes to this law. Are they support?

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Choose which

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100, they both choose to write. They

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choose. Zero is equilibrium. 00, is it stable?

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55,

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55 is 55 stable.

Actually, they are unstable, right? For example, five fights. They it loses so much, right? This was so much. They said, why not dodge? If I dodge, I lose a little, right? 55 is not stable, and then actually dodge. Dodge is also not stable. Why? Because if dodge, then somebody would say, why are you ready

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to fight?

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If I fight, I gain one, I thought I gained zero. Why are you not fight? These two? They are not stable, they are not natural equivalent, right? Not like the prisoners, diana.

So now you see then only options left is what? These two plan, though, are these two stable? One fight, the other dodge, and then the other fight is dodge on this table. Whenever you are trying to analyze whether it is stable, you just check each player, right? If this is fight, this is a dodge, and then will this dodge change the fight? No, because it changed the fight, they lose even more. Right? Now, will this fight change the door? No, because it changed the door to become zero. But now I have one right here. In this case, nobody will change its strategy. Right? Now, symmetrically, this is also good, right? Ok so you see the equivalent is the nt diagonal. It's the other diagonal.

Next one is a very famous game, which everyone of us played is a box is a paper game. This one, again, is a zero sum game. Because you win, your opponent lose in this game, the payoff matrix can be like this, 00. And then you are odd. Your friend is a scissor, and then you win your friend to lose, right? Rock, scissors is 121, right? And then just rock paper is - 11, right? Now, this game, what is the national program? I in pure strategy, if everyone can only choose one strategy, then what's the equivalent?

Now, the answer to a certain question can be not a direct answer, right? For example, I say what's the equivalent? Then it doesn't mean you have to tell me one equilibrium, right? Yeah, it could be taste that there's no equivalent, right? And this is that no matter which one you choose, right, there's always something that can be true. Right? No equivalent, right? Always, you can change your strategy. This one has no equivalent. But later on, who shows, actually, there is a so called mixed strategy equilibrium for the scale. All right? Maybe although the extreme one is a bit later, again, tell you here. So if you can choose certain strategy with some probability, then which mixed strategy, you think, is the best you want to maximize expected, winning chance.

And then you say, maybe I use 1/2 probability to this, and then half probability should be this zero confidence with this, right? Is it good? Or which one do you think is best? That can maximize your winning chance, winning probability? You don't need to come here? The correct answer just tell me a guess. What's your guess? Those

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things that show open? You can give me the last time or

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you were talking about history, but we are not yet at that scope. So we are still talking about one of play, only play once, right? Only play once. Who said I heard some

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answer. What's the wrong question side?

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Okay, very good. We got bonus, although ii think best guess I encourage the discuss, too. The guess is because the three things are symmetric, totally symmetric.

So you just give each strategy 1/3 Probability. You can prove this is the best and encourage you to prove it is best after class now, but this is not being passed exercise. Try to prove 1/3. Can give you the maximum expected payoff. No matter what your opponents choose, no matter what strategy opponents choose, you choose 1/3, 1/3, 1/3 is always best. That's some kind of thing, something that is very interesting. Okay. Now another game, soccer game. So soccer game, you have a shooter, you're goalkeeper. All right? If the shooter goalkeeper choose the same direction, losers go keep always right. And as they choose different direction, shooter losers, sorry, shooter wins, right? And the goalkeeper loses. Now, this payoff matrix, it says, you see, both choose left shooters, cut shooters, and if they choose different, right, shooter wins. The 0110100100110, and so on.

This one, my question is it a zero sum game? According to the official definition, it is not zero sum, because they add up to one. But you can shift it, right? You can shift it to half negative half, right? Then everything is zero, because if you see in this game shooter and goalkeeper their benefit, they complement each other, right? It should at least go to producers ok this one you can consider as equivalent to a zero sum game. All right. Now comes the big strategy, which I promised you earlier. Right? Now, mixed strategy means what means that you took the convex combination of pure strategies. All right. Just like the rock, scissors, paper, right? You take accommodation. What is convex combination? Convex combination just means you want the probability choosing every strategy. They add up to one, because the whole probability is one, right?

The best response, two other people's strategy is still defined similar. It. Its only difference is that now the best response also becomes a mixed strategy. You allow probability. And then nash proves that for any non cooperative gain in the normal form, with the financially many players, and everyone has financially many strategies. There always existed a national program in mixed strategy. Right? So you only see that sometimes there could be no national program. Just rocks is a bit, right? It national program, but it's always a allows the existence of natural problem with mixed strategy. Your strategy is not healer. It's always equivalent. So this is also one of the very important contribution of

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cash. Right?

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So any questions on it?

Now? These things are very friendly, right? Visualize numbers who will win by adopting which strategy, right? Now we come to the that this type single player bs interested player. That's the one you just raised, right? If, right, there are some history, right on the plate, then can I do better? Sometimes you can do better. Now, especially, for example, for the christmas dilemma, right? For this christmas dilemma, then if you know that in the future, you will face the same situation again. And then probably this time, if your partner says nothing, you also will say nothing, right? So because if you say something, your partner go to the jail for 20 years after 20 years, you face the same situation, then your partner will take revenge, right?

So probably you can negotiate after what they say. Maybe next time we choose another one at the same time, right? That would be beneficial to both of us. Right now. We come to the asian game, although the detailed example of asian game, ita will explain. I will start with the game with incomplete information.

So we first introduced the so called multi core problem. I believe that some of this, so let me just explain this now and then then see who have no seen this problem. So what's this problem? The problem says it's kind of tv show, and then there are three doors on the stage, and then there's one car behind one door, and then behind another two doors, there are very cheap things like goats.

There's car and goats. One car two goes. And then I ask you to choose one goal. All right. Now he chose, and then I say, now I will open some door behind. It is a vote. They will ask you, would you like to change your decision? Yes, I see them. No, I just see them. So for those who see very likely, you have seen the problem before.

All right. So basically, you usually you will say treating doesn't change. It seems no offense because anyway, it seems the chance is the same, but actually not. Right? So let's see, no, just to put you on the same page, let's calculate the probability of winning, of change and not change. I have three doors. This is a car. This is gold. Okay? Now, with 1/3 chance, you are here, right? This is 1/3, because you a pick a gate with just 1/3 chance that behind the gate is a car, right? Okay? And then he said, in this case, I will open one door here. I I will open this door. I tell you this is a note. Now if you change, you get a vote. Is that right? With 1/3 probability, you arrive at a vote. Right? This is a change about change, right? If your decision is changed, then with 1/3 probability, you get a vote. Because in this case, you change, you get a vote right.

Now, if at the very beginning, you chose the . bit, right?

Now this is how much chance is it? The chance is 2/3, right? 2/3 chance. You are at a gate with a goat now, because I will open another gate. It show you it is a goal, right? This one probably, I didn't think myself very clear at the beginning, but now we can kind of clear, I cannot release, I can open this game, because over this game definitely will change, right? If it's not a car. So I want another game. Who was a vote. I tell you all this is good. They say I change it, gets a car, right? That means with 2/3 probability, you get a car. This is the probability of your decision change.

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Right?

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How about you do? Not change? You do not change. Then it's very natural. It's 1/3 chance to get a cup, and then 2/3 get a gold, right? So definitely this is better than not change. All right. So this is the reflect some flavor of the beijing game. All

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right?

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So beijing game, what is beijing metric program? You should assume that you are the so called risk neutral player, which means you want to maximize your expected gain.

All right, expected gain. Remember?

Now, when, but you need to make the decision based on your understanding about other people, what other people would do. Right? You need to estimate your opponents strategy. All right? All your opponents information. Now, I want to show you a very simple example about this. How can the dog game? They always called chicken game. That's another variant. Okay. Now, so let me see, maybe I only know our first complete this. So there's another game called new product game in the new product game. The company a will may not want to do amount of this new product or whether company b will sell products at the same time ok so we need to do some market survey to collect some information before company can make a good decision, right? Good strategy. And then the chicken game similar. Now this dare just means fight. Chicken just means dodge. You see, when most people attack each other, both get zero. If both of them dodge, they get six.

Now if one person

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attack,

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the other person dodge, then the person that gets slightly more, right? Then when dodge gets nice, so similar flavor as a hot dog game or chicken game, right? Okay? This payoff matrix, it maps to the original version or the deterministic version of the game. And now let's look at a probabilistic version. Promise equation is a lot. Now we no longer have a clear, one fixed. And there to fix, you say, each player has some probability to be aggressive and has the probability to be feeble means and not to fight the other person.

Even if I now basically what people means is that even if somebody some other people attack me, it's okay for me to gosh, ii would not feel lost in my ego. Okay? It's okay. Ii do not have so much self esteem. All right? It's okay for me to watch it in case you attack.

In this case, you see when both people are aggressive, then the payoff matrix is like this. Fights will lose for sure, right? And then when this fight, this dodge, it also lose a lot because his self esteem is hurt. Why he can't fight. I do not fight that, right? So you will feel hurt, right? But when, for example, player one is aggressive player to these people, but there is a feeble one, even if you take a dodge position and the first person attack, the loss is zero.

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All right.

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It's okay for him. All right? And I do not care so much about my ego, right? Fine. All right. I see for different combination of types, the payoff matrix is different, right? And then how to compute the strategies? In that case, when for a player to compute the best response,

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he needs to know

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the probability distribution of its opponent.

For example, I know maybe my partner, my opponent, 50 % chance is aggressive, 50 % chance feeble, right? So then I will compute with 50 % chance. If i'm facing feeble one, what should I do? Right? And then the other extreme, what should I do? You calculate like this. Now I omit these parts, because these parts my tear will explain. Now I will just directly jump to how to estimate your opponents type. I think it is, you have no knowledge about that, right? How do you do? Opponent is 50 % legal, 50 % address. Now we have nature coming to play.

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Right? What

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is nature doing? Nature tells you the joint probability distribution. What does it mean to that? It tells you most people aggressive, the probability is 0 . 2. Okay? Both people feeble probability is 0 . 3 first one, aggressive, second one, feeble 0 . 3. First one people, second one aggressive 0 . 20 k this is what nature tells you. This is a public knowledge. Okay? Both of, okay, now based on this, if you find out yourself is aggressive, this is some realization because just now we're talking about probability.

Now, you know what type you are, right? You are aggressive old people. And then if you find out you are aggressive, then you will have perfect knowledge about probability of your opponent to be aggressive for people. Why easy you see if you are aggressive, then I only look at these two entries. Right? And then you see my point ba is 0 . 2. They divide 0 . 2 by 0 . 5, which is this is 0 . 5. Right? Now we know up, then the opponent being there being aggressive is only 0 . 4, and my opponent being feeble is 0 . 6.

Any questions about this? This is the conditional probability condition on your own time. You perfectly knows what type of opponent is. Right? I'm doing an easy job. I just show you how to compute the your estimation about your politics. Right? My tear will give you some examples, also simple example about how to compute the best response in terms of in the case of creation.

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All right.

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So

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next,

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cooperative game and non cooperative game. Right? Now, here, you see all the example we talk about. No matter is zero sum or non zero sum. They are always fighting each other, right? I will choose this better for me, and then you will change your decision outside, because so basically, you two are not on the same line, right?

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Now, for corporate game, it's

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a different story, but people want to collaborate with each other. Now, here there's a so called gloves game. What is this? It's a very artificial game. It says there are three people, 123, and one and two are holding a left club, left hand left club. The player three holds a right club. Now, glove, of course, some glossy, you cannot differentiate whether it's not. All right, we do not look at those one. We look at those last meal which can really differentiate that. Right. Now, what is glass? If you have a pair of glass? Like this, a pair of loss, then the worst is one. You can earn $1. You can sell a lot of other people. You have $1 back.

Now, if you don't have a single glove, no money. All right. Now, what's the question? So the question is, if these three people come to play a game, all right? And then how much money you

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should pay each other so

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that they are happy, or they feel sad. Right? Now we see in our city, clear, she holds the right glove, right? But this is only right about. So psg is very important, right? By intuition. You would expect you spend, please, you should get more money back because his object is indeed. Right, okay.

Now actually, many years ago, sharply decide be discovered or is that I should not say discovered, sharply design a protocol, computing how much money should give to each person. That's very interesting. Right? So the process is made false.

Now, I will you on show that in the next page, but here i'll just tell you for player one and two, they get 1 / 6 dollar. And for player three, it gets 2 / 3. How is it calculated? Basically, the way to calculate is the form. First of all, you give total $1 to all three people, right? This is what the second it says. Now I try all the possible arriving order of the three players. 123, 132213231312321, or 6, right? In all the 6 sequences of arrival. I calculate a certain players, marginal contribution. What does it mean by marginal contribution? Means? Before I arrive, these old people, they already can generate a certain amount of value, right? After I arrive, how much more value i'm great to the community. This is marginal value.

Now. You see if your sequence is 123123. Now, one, and two, actually, they didn't generate any marginal value, because when they arrive, there is no right of their left glass is useless, ok they to generate zero marginal value. But three generate large value of one, because whenever the right block arrives, you have a pair, right? And you have one block.

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Right?

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Now, you can see, actually,

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for

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people like this, for people like one, only in one sequence, it is valuable. Their sequence is 312. Right? Why? Because in order for what would be useful, it must be the case that when he arrives, there is exactly one right block, no left block, right? And so only cases one arrived after three. It is valuable, right? If one arrived late in the third position, then two of the three already have a pair. One is useless, right? If one arrived earlier before three, one is useless, right? Because we didn't write yet, basically only one sequence will give you the margin value of one for play on. Then because there are six sequences. This is a marginal value. One can give you in the sequences. This is the aggregate value only, because one is only useful in one sequence. The uses in what the sequence is. The total value one can get is one with marginal value 1 divided by 6 sequences. This is why player one will get 1 over $6.

And then symmetrically square two will get also 1 over $6. And then because the total amount of money it gives to three players is one, 1 - 1 / 6, - 1 / 6 is 2 / 3. This is the amount of money players three can get. So you see, for this concept, it matches without intuition that player three should get the most amount of money, right? Because this item is unique. But at the same time, it quantifies, how much more players we it should not get all the value, right? Please, we cannot get one more for sure, right? Because without one n two, please be something as well, right?

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Now,

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when we talk about over the games in the next week, we talk the next week, seven will talk about the details of the structure back. Okay. Now there is another interesting game called stack over game, also called leader follower game. This game is a pretty interesting. Now the two players are not symmetric. They are no longer in the same position. One of them is more power, is also called leader. The other one is followed. Leader will promise something. Leader says i'm going to adopt this strategy. All right? And then follow choose what he did. Okay. Now it seems similar as the usual normal form game. But the interesting thing is leader only make a promise at the very beginning, although in the end, it really needs to choose that strategy, but the game philosophy changes a lot.

Let's look at one example. Now this is a a usual normal game.

Now, let's first look at the national privilege of this game. Maybe I should use this door because this one is closer to the center. Now, this one, if you are here, right? If you are here, then leader will be very happy, because also role as leader ok remember role as leader, columnist follow up.

So when you're here, definitely role player will not change, but the common player will move to this place, right? Because one is better than zero. This is i'm going here. Now, when you are here, will leader change again, right? Leader will not change because you see changing become one, right? Leader change become one. So basically, this one is a national program, right? 21 is a national program. Do you agree?

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Okay.

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Now, next, 10 is not stable, because 10 role player can move to this role and becomes 212 is better than one. This is not stable. How about 31 about 31, the 31? Again, role can move, right? The move possible. So basically, 21 is the only national, right? Okay. So now, let's analyze on the leader followers scenario, leader followers. Then leader says, if I choose this role, what will follow them? What will follow them? If I choose this one? Follow, definitely choose this one. And then he just says, how about if I choose the second? What will follow the? Okay. Then you see, if leader choose the first vote, he knows that you don't get to the back.

If leadership second row leader knows, I guess three, because formula is rational, remember, so he wouldn't choose the second column if I choose second row.

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Now is

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for leader, then which role do you set your pick? Second, right? You pick the second, and then you can get three benefits. But remember, we said 31. Is it nash equilibrium? No. But we need the following leader successfully secures three game by committing to some strategy. Is that right?

So that's the difference between national program. And this leader follow again, because you need to follow again, because leader is more powerful, right? You can gain more than what do you get the national group? The only sacrifice he did is to commit to some strategy. So leader said, I will definitely choose the second row. So please make a decision. And then the follower trusts the leader, right? So this is where followers says then I simply choose this one, because i'm sure you will not cheat me by choosing the first row, right? Okay? You see, stack over game, it can give you right or keep the leader more space to gain profits. Right? Any questions here?

Let's we look at some examples and also paradoxes.

Now, firstly, let's look at the so called shortest path options. For the shortest path options. A buyer wants to buy a pass from st in the graph. We want to let the buyer pay less amount of money to buy the pass.

Now there are some analysis in the middle. Let me just show you the figure directly. So this figure, the number on edges, they are the cost of the edge. These costs are reported by the edge themselves.

So basically, every edge is possessed by one player. On the network. Every player holds an edge, and they will tell the buyer how expensive my edge is. Right? So if they tell the truth, then the buyer is very happy, because he can buy this half, 00000040. The buyer needs to pay nothing, right? And then he buy, he bought a pass from st which is cheapest. But the edges, they are selfish, meaning they would like to cheat about their costs to get more pay. For example, this zero, it says, okay, how about I achieve to be 0 . 5? And will the buyer will still buy this? Because this is the cheapest one. Then I get $0.5, so

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then I will cheat.

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All right. Now, the buyer says please do not cheat, because cheating will make me pay a lot, right? So the buyer would like to pay somebody such that it will not cheat. Then. How much do you think that you should pay this edge? Zero? What for

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investment?

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One, european one. Why? Because this edge can cheat to be 1 or 0 . 9, right? This part is still cheapest, right? Because these two are one, right?

So every edge here, they can bargain for opinion of close to one another. Right? Then in order to buy this pass, the buyer need to pay $10. Right? Okay, that's not good, right? He wanted to let the people tell the truth. The buyer paid a lot of money to buy the actual zero cost pass. Right? That's not good. But in order to make people tell the truth, maybe this is the best buy to do, right? But here there's an interesting phenomenon. Actually, this is also a somewhat a dilemma. So usually we know more competition. It should be better for the buyer, right? More competition, right? So many people want to do my project, and then I can choose the one who can well accept my lowest price, right? But now here it is trying to show you that less competition we're going to pay,

less competition be 12. That means that, for example, the buyer says this person I do not allow you to come. I just forbid you from joining the same.

That means less competition, right? Then you see, if I cut this edge, then nothing here. It's not possible, because without this edge, the past above does not exist.

In this case, then the buyer has two choices, one and one, and then he just can choose one of them, pay $1. This one will not cheat, because if this one cheat, say i'm one by 1, then the buyer will choose this one. Right? They have no bargaining power because they are equal capability. This is, you see, the buyers can pay $1 to buy a pass, not all over $10. Now this is 1 kind of minor paradox because you reduce the competition, you gain, right? You didn't lose, right? Okay? Now for games, right? So actually, there you can classify them into different categories. According to whether national criminal exists or not. So that was the game where national products like this. You already see it right across in the paper. There could also be game where the national criminal exists, but not every past convergence to national criminal. What does it mean of?

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This

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is the status, right? It doesn't rules be true. This person will improve, but maybe there will be some cycle. Right? After this one round, how many come back to the original status? And they move again, right? There's a cycle in this best responsible.

And then The game, the national freedom cannot be reached by every pass, right? Cannot be used by every pass. Now, the last one is the most promising one. It says the national criminal exists, and every pass converts to the national group. This game, you have a so called potential function.

Now, I think that I will complete this example and then take a break. So we'll take a break a bit later. Now, this example is called

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total

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distance game. What does it mean? It means that you have n players. They played on the graph with n vertices, and each player will choose another test. Now, what's the players? Benefits or gain? The players benefit is its total distance to all the other players. Basically, the farther away from other opponents, the heavier I am. I want to be far from now this game, which category does it option?

We have three categories, right? Which category does it belong to? Bonus question?

This question is split into two parts. You can either guess. First, the correct guess will also get one's. And then you need to reason about why that is the case. But remember, if there are two wrong assets, the last one will not get a bonus, because altogether we only have three categories, right? Any first guess, which category does it belong to? Second, this one. Okay. It's not correct. Which one? Third third is correct, half bonus. Then why national criminal always exists in every class conversion, national criminal, or you have a potential function. That what does it mean? It means that the potential function means what it means, that you have a function related to every status of the game. Then whenever somebody make a move, this function value increases. Somebody make a move, which means somebody make a move is in this player, improves its benefits, and then the function raises and et cetera.

Because you keep raising the function, there will be limits, right? They will stop sometime, because it would have limited status. Number of states in the game. When they stop. That's a natural proof. The middle is possible. The function always increase. Therefore, every path will lead you to measure. Right now, the second half bonus, you need to design the potential function, which is calculated based on where players are in the graph.

I guess I hope you do 10 minutes break. Meanwhile, in finance company and you get the other half bonus, 10 minutes break to be these annaninoo

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therefore, you look at it. 1. They for two or four. Or

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you should be mix. And

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so you are now make some your son and we should back on the road too. Sure, should probably not txt.

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You can

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go. This should be fine with god, is beyond so they are. So I think it n

说话人1 56:31  
you. There are still 3 minutes to the bonus deadline. What you need to do is to find a potential function. This function will increase the value. Every time somebody moves to a better place, when set, better means a larger distance to other players, larger total distance to other players.

Very good. How about what distance the

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is? A very

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some of every players for the distance or some of mutual distances between any two players. That's the potential function why this function will increase every time. It moves to a better place.

Now. Remember, if I am a player, I do, then other people's distance. They will not change, right? Other people's mutual distance, they do not change. I if only I knew it right, and then when I knew it, my distance towards the other players increases. That means my part of the distance, right? They increase, because the function says all the mutual distance between players, because my part increases, other part doesn't change.

The overall function increases no matter which one moves, that person will cause the increase for the mutual distance summation of all the people. Right? That's why using this function, you can show it is a potential function, and therefore, every path will converge to a national.

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Right?

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So take a small risk and will continue very soon. Yes. Now we come to the next paradox. So this is also a very famous paradox. So basically explains why in a city, you have one more highway. It does not mean your traffic condition is better. All right? This product tells you much. Now, suppose on the left, you have a two parts from s to t you have many cars, one unit of a car. So they can be split in arbitrary, small granularity. So on, every edge, there is a delay function. Delay function says, if you travel on this road, if the total amount of traffic travel is x your delay is x then you on this road, the delay is always one, and then reversed on the other task.

Now, in this original graph without highway, there is one equilibrium, because we have two paths. Every small people they want to choose the faster path. A balanced condition is that half the people choose the upper part, half choose the lower part, because it is tough that the delay on the upper class is 1 . 5. Delay on the lower part is also 1 . 5. No matter which group of people go to the other class. The day is longer, because originally is half, now it becomes half the 0 . 51 of local delay, right? Nobody will go to the other path in a stable condition, 1 . 5 delay up, 1 . 5 delay down.

Now let's see, the government is very nice. It's okay. Let's open the highway here. The highway, because its highway is delayed, zero, no delay. Let's see what would happen. Our focus on this paper because this figure is closer to the center.

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This is

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a highway. So for people traveling this way, they think after I arrived here, I will not go to this part, because this past delay is one. I would rather go here because at the very beginning here, the delay is only 0 . 5. Right? More and more people choose this path until every upper group they choose this path. And now what's their delay? If every other group choose this path, what's their delay? 0 . 5 +, what's here?

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One very good, because when all the people here choose this path, then the lower is still here, right? All this edge, the total traffic is one. So the delay, after all the people shift, it becomes 1 . 5 again, which means this group of people, they didn't benefit right? Originally. They are 1 . 5, but because of this, they gradually also become 1 . 5. Although individual is good, right? Less people who is good.

Now, that's not the end. You see the lower part now has a delay of two, right? They are very unhappy. So why you come here, come down to take our parts, right? No, not good. Now it is too. So I will not do this anymore. I will do what? I will change from this part to this, because now there's only half people here, but this is zero, right? I if I change to this place, I can reduce my delay. Right? So then the lower group also changed to this part. And then in the end, what's the delay for all the people? Two? Very good, one kid, one kid. She has two. That's the equilibrium, right? After getting the highway, your delay changes from the earlier 1 . 5 to the current two. The highway increases the delay. Right? That's a good. There's a paradox because usually adding more resources, the congestion will be alleviate, right, less congestion, but now more congestion, right?

Okay. Now, I will briefly mention another related concept of another game called isolation game. Such an isolation game is a broader class compared to the total distance game. We talked about earlier what size of the game. I think the game says each player wants to stay away from other players. So it's very useful when you try to locate the shop, because when you look at the shop, you would stay away from other shops such that you can have your own character of customers, right? Because customers usually go to the closer shop if they are of the same quality.

Okay? Then it's also useful in product design, because when you design a product, you hope your product feature is not very similar to another product. If it's very weak, then you can sell at a good price. And if it's also useful at the same time, then it has a similarity with the so called runner game is what means that it's just you have a two d space, and then you have people in the space, and every person is a point, and this point will have a territory. And the territory include all the points which is closest to this point.

So basically, when you have two points, only, it's just a cut the plane to two half points, right? This half angle to this point, that half angle to this point, whichever point is closer, they go to that point. So this is a wrong line diagram. Okay? Now isolation gate says that if you have the several points like the red points, and then the players, the blue one, right? And then suppose there is one process here in the middle of this red, one of this yellow one, and then it has a distance towards other players. Then I sort the distances from the smallest value to the largest value. Then I apply that weighted a weight vector, weight factor, w one, w two, wk and then every person tries to minimize or maximize the utility utility is what? The distance multiplying the corresponding weight vector. So everyone tries to maximize this one.

Now, you have different kind of utility of the weight vector. For example, there could be a one single entry being one, others are zero, which means I only care about one certain player, for example, my closest competitor, right? Which one is closest to me? I want this person to be as far as possible. Okay. So there are many parents of this kind of game, including monotonic rate, increasing, decreasing, or every weight is one. This one corresponds to the total distance game we talked about earlier, because you end up all the distance to other players, right? I want to be far away from all of them as a whole, right? Okay. And then here I will omit the results because there are many categories, and then there are some situations where the equilibrium does not exist, for example, in a a symmetric case, which means the red edge, the black edge is length two.

Then when you move, so for example, in here, then the the blue one, we will hear, sorry, aa little misalignment ok so because the original 1806, the yellow one has a distance to towards it, because when he looked at the red, look at the yellow one, he used black, yellow ok the driver was true. He thinks it's true.

Then over here, this end here and look at the red, the yellow one using the red arrow. Then that's become three. So the blue on the moon, right? Because everyone will be far away from the other one. So the blue and then the yellow one says, now I look at you, you just your distance to be is only two. Because i'm looking in the direction of the black one. And then I will move to this place. And then I can look at you using the red arrow, which is three. And then we want to move again, again, treating the distance from 2 to 3. So then this will go on forever, but never stop. So in this case, there's no national criminal. And then actually, this instance can be extended to end players. Not only the details. It's a pretty straightforward. Okay? Yeah. So basically, there are many interesting results. The most interesting one probably is this one. When your weight better is something, I don't care and one.

And then it is gonna be hard to decide whether some configuration is a national credit, then where the wave vector is 00001, and then something I don't care. And then it is quite a number of times. So ai think, will be the most interesting classification of the difficulty of the crowd. Now, let's come to a brief summary of the topic today. Now, basically, game theory, right? It originates from economics. And then later on, computer scientists look at the problem in from another end, basically, from the computability end, because economists, they usually say, as long as I know,

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it exists.

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That's good enough. Something exists, for example, national equivalent exists, old enough. All right, I know this market is very good. But then computer scientists, they focus more on what? Computation, whether it is easy to compute that equation. If that's good, right? For a little time computer, that's nice. But if it's a bit hard to compute, maybe not so ideal, right? Okay. So they made contributions to both modeling and also the computational perspectives.

And actually remember ppad complete that come complexity class. And the line problem is designed, discovered by this great scientist of individual. Okay? And also there are many other famous figures here. I'm not going to explain who they are, but I guess you could know them by using a lot of ai recognition.

So I do not know every one of them, but I know some of them. Okay. This area, we call it computational game theory or algorithm game theory. So basically, using the computer science perspective to address game theory charges, right? And then among them, it's a computing and evaluating equilibrium concepts. Now, people also study the representation of games or application of games. Now, actually, the sometimes, just like when you see some problems on behalf, what we'll do is try to design some approximation.

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Right?

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And then here, again, common question. What if you find out that the computational question is hard? And then probably you can study games with special structure. With the special structure allows polynomial time computation. Also, you can look at the brute force algorithm to find equilibrium, even brute force. We know there are some smart integration. Remember very well the first lecture. And then we could also design faster integration algorithm, right? Then you can look at efficient algorithms for heuristic to compute a approximate equilibrium.

Now, what is the question? What do you think is approximately, that's equivalent, right? I changed to another strategy. I will not gain more, right? What is approximate nash? It seems a bit untraditional, right? Because earlier, when we talk about proximate terrorism, we have optimal solution. There's a cost, and then approximate means of a solution. The cost is larger, but not too large, right? Within 2 times or 3 times,

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the national caribbean

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seems a bit tricky, because it does not have a

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cost

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unless you use the poa or pos but we do not get those c just to be a stable status, right? How is the approximation? And

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so maybe you can a

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find a way, a

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second, the same code, the circle,

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the

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the

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rain arrange, it's, okay, but the range need to. I know what range it is, right?

For example, I I I know roughly what you mean. So basically, if I change my strategy, I cannot gain is a natural program. But if I change my strategy, I can gain

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only a little.

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Right? And then I also not change because changing needs some effort, right? I should expect to gain sufficiently large gain before I want to change. Right? This is a one possible definition of approximate, equivalent, for example, epson. When you move, when you die, when you change your strategy, right? You cannot gain more than epsom. Then it's a epsilon nash. Right? But this is one thing. And then it also study alternative solution concepts. Okay. Now, one thing probably you will know you will need is that whenever you look at some problems, all right? And you try to address the problem, but then sometimes and you can learn to plan, because in reality, as I know, is it is, okay.

So in reality, maybe the information is not known to use. Other people's strategy is not known to you or the payoff. Right? So the how how good an outcome gives to you is also not very clear. So you

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can only learn

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the optimal strategy all the time. So you play something, you discover something. You say this strategy seems not so good. Then I can try this, right? And then try that ok so gradually we know what other people do, and also what's your own benefit? Performing certain actions. All learning again, is also very important. Okay. Now, there are some kind of the problems that without learning, for example, there are so called no regret learning algorithm or target learning.

Now, the important thing to know is that whether you're learning finally will converse equivalent. Now, this is more mathematical, because proving something converged is highly appreciative. All right? Okay, now, but anyway, that the learning sometimes will be useful, right? In getting your awful planes charged. Okay. Now, the next thing you will look at is that whenever I have some real problem, right? Can I look at the problem from a game theoretical perspective? Mostly, the answer is yes. For example, if I give you the game and then also a related, incredible concept, they can I show criminal exists? If can I find it? Find one or find all put it on? Right? And then I want to show, does there exist an equivalent in which certain other criteria is maximized? For example, social welfare and what benefit the global society gets, right? All pay off whether some players get at least expected payoff of b or whether you have unique equipment.

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Right?

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So all these questions are possible. Now, for modeling the general game, usually first will do the mathematical formulation. You try to define the intimate function of your game, right? Then this is the assumption will depend on some parameters that is affected by

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agents actions.

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And then you try to find a related equivalent concept such that you can compute that problem for your game, right? Or you show up computing this is hot, right? In general. Right? This is the second step. The third step, you may run some experiments. Simulations to show how good your city is, right? Or how often or how certain your problem will be computed. This is the general three step approach to deal with the general problem. Now, actually, in reality, there are many interesting games. And among them, the broad category of games, as on security gains. I've only heard about security gains, maybe ten less than 10 years ago, but the professor initiated this security game is very, very famous.

He's now a professor in harvard. So basically, what he did includes the following, for example, in airport or in the postcards. So there are sometimes some bad people. They want to destroy some facilities, right? And then you also have the security patrol. You can allocate resources to to control different events, to catch those bad people. So this is a game between good people and bad people, right? So how to distribute resources to different posts, to maximize the probability, to catch the efforts or maximize the probability that protect the facility. Right? So that's a very important issue. So this is about the physical security, right? And then there are also green security, which means that you have wild animals. And then there are sometimes illegal hunters trying to catch those wild animals. And then you have a power which can deploy to different values, right? Different forests, et cetera. And at a certain time, such that those bad countries will be frightened to go to do bad things. Right?

Anyway, it's aa security game in the green world, right? And there are also some other games like the of cyber security game or other kind of security games. Okay? So now there are not many more other games, but I think that here i'm not going to elaborate more. I just mentioned one thing called in influence maximization game.

Now we do game first and say just about influence maximization. What is that? So imagine you have a company and this company wants to sell its products. For example, they want to sell iphone. And then one strategy is the company and the apple. They give five free iphones to five people in the social network. And then these five people would be their ambassador that promotes all this happens very good, et cetera. And then the people around it will be affected. They say some of them will buy, right? And then the effect will propagate the whole network. Right? And then the goal is what the goal is to choose. The most influential five people or the best five people, which can bring them all those benefits. Ok this is influence maximization.

Okay. Now, so here, basically, as we already mentioned, right? So the three step study model, right? Formulate the game, compute equilibrium, analyze the equilibrium, and finally, experimental results to that is something.

This is some slides I reference for the topic today. And I think that I will give the remaining time to my ta to share with us the patient game. Do you want to use this book? I think you can use this book that can share and then use this book. You don't need to connect to the

then in china, because I think the writing field is even better.

说话人2 01:27:44  
Yes.

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I think so, right. So can you see clearly those? Write on the board? It's okay, then I can write on the board. Can you share the pdf first? Your question? Share a question first, then

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just maybe

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you just survive on the board. So you also internet zoom to share a question.

说话人2 01:28:15  
Ok together in this area is an example which game. So in this lecture, we already see a home game with a certain they are mistakes, and all the information are on the knowledge to all players, invasion things. So they should be also known as incomplete information.

And so let's say incomplete information. So in the vision game, there will be some private information about which individual player that are not known by other players. So let's see a scenario of beijing game to see what this means. So this scenario is this. Two people are good friends who are excited to go hiking or reading books on me. They have some actions need to go take. Each of them has too many students have opinions again, independent it, it cannot be. One of them is extroverted. This let's call it player. One. A is ab person who like hiking very much, but refers to always her friend. The other of them is introverted. We call it layer two, enjoys reading books more than happy, and sometimes prefers to be with her friend and sometimes prefers to be alone, want to enjoy some quiet time alone.

So the introverted person knows her preference today, but extroverted person does not. So we can see there is some information about individual players that are not known by other players. I like the wrong thing. But the extroverted person thinks the probability that introverted person prefer a company today is 3 over 4. So about this private information, although other players may not know these players private information, but they know some news about the private information. So the situation is summarized in the following tables. So according to whether the introverted person enjoys interest is coming or not. So we have two different developments in the table. One. Ii personally reversed in person time. Then we can see these are the abilities. So the first in the sale of the first item is the utility get by the they are one in person. The second item is the university of the I person.

So you can see if I person wants her friends company, then if they choose the same strategy, and then they will at the high return to. If they are separated, then they get zero. And then in the second table, 5 % prefers to be alone. They choose the same strategy as much as that lower ok so this is a scenario. And that's we let's together describe this situation as a patient game. During this description, we can see the ingredients of a nation game. So in a normal game, we already know that we have a player sense, strategy set and pr mistakes, invasion game.

Also, first, the player two players. First is the players that the players player. One is in person player is I this is a person ingredient. And the second is the type invasion game. We use the type of the, we associate the type to each agent to capture the private information that each agent to us. So very nice. So let's use t one to give the there once time. There are ones in person. She has no time, right? We can actually assign, for example, c so she has no time or we can say she has only one time is a taste. The t two, the other person has that that's use the a and b character, indicating that so aa type means a type means I person once for a grand company. Once in this. So the I person has two different type in this is and then the set the third ingredients is their strategy set.

So as the in person, the strategy set is very clear that either choose go hiking or choose reading books. So either h or r for the second person, for the player two, the I person. Here is the strategy will be a function of the type. She has two types. Under each type, she can have two different choices. We use this hh hrrh each of, for example, the hh means if there are two, the I person is the type a which means she wants her friends company, then she will choose h or the hiking strategy. And if she is the type b then she also choose h strategy. Hr means you choose type a then she will choose h if you choose type b she will choose r so the strategy of ai person will have this form instead of the the normal game, right?

The normal game, as you will, also be like hr so not that she has different types. The strategy will be a function of her. And the beliefs, although the e % do not know I person's private type this information, but she do have some beliefs about this narrative mission.

So I think the beliefs, so these beliefs are represented as a probability. The p one, the player ones, same. Given the player ones type, she thinks their tools have is a once the company, this probability is that here is 3 / 4. Even the happy, see, there is happy space, probably is one over four and the p two. So this is a fair since the 301 only has one fixed. So this was the one. This is simplified scenario. So in other scenario, the the e person, the first player may also have the several types. Here, I just use a fixed type to that she has a local. This is a several in ingredients of the nature game. So players and types and the strategies so that it has specials that he said and maybe is about this. About this game, let's find the nation nash equilibrium.

In the lecture, we see in the beijing game nash equilibrium definition is in the beijing game. Beijing nash equilibrium for risk mutual player is defined to be a strategy profile that maximizes the expected gains for all players, depending on what each player it is about the strategies chosen by the other players, actually expected games.

In other words, given a strategy profile, each player should at the best response for the other players strategy. A very straightforward way to find patient nash equilibrium is. First, we find all strange, all possible strategy files. The strategy compiler is is all the strategies that they can be taken by the players.

So, for example, hhh is one possible strategy to hire means player one. So in this game, player one, choosing hygiene. For player two, if she is type a she will choose ip and choose type b she will choose ip this is a possible 35. And so remember that s one contains two strategies. S two contains four strategies. Probably we will have eight different strategy five. For example, this is also possible second time. You can list all of them and check each one. I will showcase possible. For example, check this one. So whether this one is a nation, I should equilibrium, let's say. Let's see whether the h is the one's best response. If there are two play hh strategy and the universe way in there to choose hh strategy, whether h is player one special response for the player station.

Okay? For example, you pay one. Let's see, the pay off matrix to decide whether to change the next response. If theta one choose h then that e percent is theta one, I percent is theta. Then we can the player one chooses h and player two is type a then we can go into this role and see, compare these two numbers. We can see in player two, choose h she will get to it in player. To choose. They are and she will be zero because so the man who will choose or at that many friends, if I use best response for the abbreviation, they are for the abbreviation of the best response, best response of player two, when she's facing h of player one strategy, then it is equal to type a so it should be h if player one choose h player two is type b then you compare the these two numbers.

You can see where to choose r will give her more utility, so it should be r you can see hh is not the best response for the advantage, right? Hr should be the best response. Until here, we can conclude that this is not a of ancient national degree of time. Let's then very verify that hhr whether this one is the is the patient actually different. So we already we already verify that if they are one choose h then hr is the best response. They are two h two equals hr the next we want to verify is br one. The pr one's best response for hr whether this is equals to h or not, if it is equals to h then this is a nation that's compare h and rs, exactly games.

So let's see. They are ones utility for age. Hr is equal to, since the player two has 3 over 4 probability in a that is this times hh we will, is first the matrix, find the matrix. It. There are 12 gauge, there are two also two gauge, then the utility is formed. She has the player one has three or four probability to gain utility 4 plus one over four times hr we need to focus on this number, and because she has a 1 / 4 probability in this scale matrix, get to 10 to 0.

It will, if the player one choose h she will get to 23.

And we compare with this number. You are the hr she has three or four probability playing this matrix, the first matrix. The way you can find the rh this is the zero + 104 probability rr then we can see that this one is bigger, right? The expected gain is bigger. H should be the best response for player one. When facing the player two is strategy is hr hhr is is a patient that should be. You can continue to verify each strategy compile.

Next, I will briefly talk about how we in speed up this process. We can first observe something like the br the best response of player two. When they are one to the h it is a we just see it as they are, right? And then we can observe that the best results of player two when the player one to r so you can see they are 12, are then you compare these two. Number four is a larger than zero. If there are two is is in the type a than children are. There are two is type b then she will choose here. She will choose h this one we are only very verified into is a nation equilibrium. And the next we need to like the utility. You tell you what are equals to. Again, you use probability and times the corresponding utility to calculate. They exactly gain in the right.

So for example, in utility is player one choose r and po two, then player two choose r and time a then to be 13 or 4 + 1 + rh the expected gain for this strategy. How is this? If you want in their hr then it is equals to hr zero plus hh for is to one. This is the h is the best response for rh is er one. Rh is equal to the h not r you can see the is up there. Two choose rh strategy. They are one will not choose r but h the the rrh this is not a nation.

Then we can good that only h hi is the unique match. This. What my sentence? The whole thing is like this. This example can, in several ways be more general or say, more completed like first, we can. The first agent only has one type, and the second agent has two types. If the first agent has also two types, then you may need to enumerate the all the 16 possible strategy file. Second, if the probability p is given as a parameter, instead of a a constant, then you can see these numbers. The calculation results will be will involve the parameters. So you need to discuss the peace range to decide which strategy has a larger expanded thing. The results should be like, if he is within some range, then this strategy compiler is a nation equilibrium, but the other then is not nation.

Here, the conditional probability is already can be summarized from the scenario description. The other time they may give you a joint probability distribution, you need to use bs rule to populate this initial, but like this thing in the then

说话人1 01:51:35  
thank you. So I he will post these notes into the palace, so you can access to that. And by the way, also for in class exercise to

part one mean on the canvas. Basically, after the next lecture, the third question will be there. And then all three questions for first part, in some in class exercises are there. And please submit before october 21st ok so that's just for

说话人2 01:52:09  
my class

说话人1 01:52:10  
ok now see you 2 days later.