Artificial Intelligence
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Lecture-34
Adversarial Search: Horizon Effect, Game Databases & Other Ideas-Part-6

So welcome back here we are in our course we have been talking about game playing and adversarial search. And so far we have casted the sequential 2 player game adversarial game as a minimax search task.

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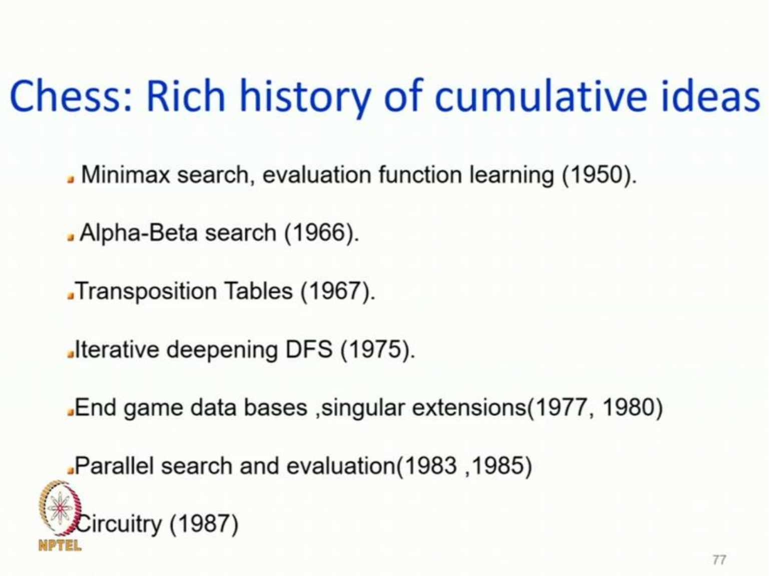

Chess: Rich history of cumulative ideas

- Minimax search, evaluation function learning (1950).
- Alpha-Beta search (1966).
- Transposition Tables (1967).
- Iterative deepening DFS (1975).
- End game data bases ,singular extensions(1977, 1980)
- Parallel search and evaluation(1983 ,1985)
- Circuitry (1987)

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And moreover, we have said that look, we cannot search the minimax algorithm till the very end and moreover minimax is slow. So in order to speed it up, we talked about alpha beta pruning, which effectively doubles the depth of the search that we can visit in the best case but that is not sufficient either. Because we cannot go to the end of the game and that is because the games are long the total number of steps that the game may take is very large. And so eventually we need to stop the search somewhere in the middle.

And when we stop the search somewhere in the middle, we need to figure out what is the value of the current cut off point that we are able to backtrack, all backup update up. And that particular value evaluation function is the key of game playing in some ways. If we have a really, really good evaluation function, we need not do any search whatsoever. We know exactly which move is the best based on just looking at if I take this action my evaluation function says you will get this value.

If I take that action, my evaluation function says you will get that value. So let me not even do my search. Let me just do one step. Look ahead and figure out this is the best action I should take but of course, typically, my evaluation functions do not get that where that good. And so I do some search, but then I have to cut off. And when I cut it off, I need to define decide the value of that point. And that is computed by machine learning.

And machine learning generally, is this idea that a machine can learn based on experience or data. And in this case, the data can be historical games that have been played for this particular game between 2 players or it could be your own experience that you are playing against yourself, you win or you lose, and you back up the values. And then you give your agent to your opponent and then you started moving again.

And that is sort of what the standard machine learning algorithm in this case would do. Now, this, and many other ideas came together in making the good chess player. The chess as we all know was one of the most important games to demonstrate that machine has intelligence. In fact, the history is not just 50 70 years old. The history dates like really, really old. Does anybody know about Mechanical Turk? Not of the Amazon variety? Does anybody know about Mechanical Turk? Yes.

What is your name? Fetish, tell me about it. That is so Fetish it was a fake chess player. There was a man sitting inside a big box, who was playing chess. So the story is that this is this goes back to late 1700s actually, I think this happened in Europe, where they created this very elaborate mechanism so that nobody could find it. There could be a human sitting inside. And this human had very short height, because of which he could squeeze inside this box.

And there was elaborate gadgetry that somebody opens the door it looks like just some you know, gears and so on so forth moving around, and they were powerful magnets such that this player could play the game sitting inside. And so and this player was a Turk Turkish person, which is why this month this, the secret was revealed this particular gadget started to be called Mechanical Turk.

And this particular idea is that you think that the machine is playing so what would happen this magician or this person will take this, this big box to say that I have made a machine which can play chess and people will be like of course that is not possible so they will play a game of chess with the machine and the machine will win because the Turk actually knew how to play a good game of chess.

And everybody would get amazed they would, you know, open the door here they would open the door there they will be able to see through. However, you know, this was arranged using all the tricks of magic at the time, and they will feel like the machine is playing this. It is a mechanical device. That is playing the game. So eventually Mechanical Turk started to be called as a general word for the phenomenon when you want machine to do something. But eventually at the back end, a human is doing it.

Does anybody know about Amazon Mechanical Turk? Nobody this is your homework, you must read about Amazon Mechanical Turk, just for the general knowledge. I mean, these things are things that are happening around us. So you I mean, I am not saying that mechanical just started today Mechanical Turk started, you know, in early 2000s in the 2006 2007, I think timeframe.

But the idea is that this is a market place for people to work. So, you have a task let us say you want to label training data or you have images or you have, you know, bills that you know, people have you are magic pin, I do not if you know do you know about pin dine out you know about dine out good you know I like which world are you living in. So magic pin dine out all these are you know mechanisms.

Where you eat out you take the bill and you take a picture and you give it to magic pin and say this is how much I paid 1000 rupees for this meal and magic pin will give you some points that and you can keep accumulating your point what is in it for magic pin magic with knows who is eating where what kind of food you like what kind of food is sold in this restaurant and what is the typical purchasing power of you what is a typical you know, price of meal of the restaurant etc.

And then they can monetize this data. Long story short, suppose you did not know how to do OCR or your bill was the picture was not taken just perfectly and so on so forth. What would you do? You will try to give it to the machine the machine will not be able to do give you the correct amount they will not be able to verify I mean they need to verify you say that I spend

1000 rupees, but eventually you only spend 20 rupees and they you should not get credit for 1000 rupees. So, essentially what we do is we give the task to the machine.

But behind the machine it is a human sometimes. And this human actually does the labelling. And now, this is not secret, everybody knows that there is a human great and one such marketplaces, the Amazon Mechanical Turk. And this whole phenomenon comes into this form of crowdsourcing that you do not know who is doing the task. Somebody from the crowd is doing the task, but somebody is doing it.

It is like you asked a question on piazza and at TAS, TAS do not get the time to respond. I do not get the time to respond, but one of your fellow student's responses and gives you the answer, but this fellow student chooses to not put in their name on the response. It is anonymous to you, then this would be crowdsourcing. You had a question the crowd gives you the answer. In fact, the crowd can come in and say no, no, this answer is correct, they will cut it, they will improve it, they will edit it, they will it will give you a better answer.

So piazza is one way of you know, crowdsourcing information, another famous way of crowdsourcing information. Wikipedia before Wikipedia there, there was encyclopaedia Britannica I think they are going out of business or if they are not, they are the only encyclopaedia not going out of business, something like that. All lines, encyclopaedias have gone out of business at the time they were people who would write encyclopaedia by hand.

I mean, of course, Wikipedia is also written by hand, but individual people who will be responsible for individual essays and so on so forth, they will have some quality control, they will be paid in a huge amount of money to be writing in encyclopaedia Britannica. Now, anybody can go and edit anything, but the point is, then somebody else will moderate it and then they will be a mechanism.

Which will get it and so this is all outsource mechanism, the quality control is crowd source, the original sourcing of the article is crowd source, as an event occurs quickly it gets onto Wikipedia because it is crowd sourced if there was a person responsible for that article was always editing it, you know, you would be dependent on that particular person to actually make the edits that would not be scalable.

So, when crowd comes together a very interesting and nice properties happen in for example, in Mechanical Turk, you could be sitting in Africa, you could be sitting in Eastern Europe, you could be sitting in us, Philippines, you may not have sources of income, but you may have an internet and if you have internet you can go to Mechanical Turk you actually get an account and you can start getting paid for the small amounts of work that you do.

And in many economies which are not very rich, even though you are the amount of money you make per task is small, that adds up and that actually increases the quality of collection. So it was seen about in a few years ago when this demographic study was done that a lot of people in on Mechanical Turk were from India and Philippines and different countries where the overall cost of living is low.

So it democratized work, actually, to some extent anybody can get work. And that is the beauty of it if you have some skills. So that idea came from this idea of Mechanical Turk, which was a chess player where you know, you are giving it to machine but internal there was a human doing it. And so this whole intention that look, we need to make a good chess player was very important in the minds of AI researchers.

Because the history of Mechanical Turk and history of chess as an important game for intelligence had been allowed and I also told you that even from the very beginning when the word AI was coined in as a field started people were trying to play chess. And of course, minimax came very quickly It is a theoretical understanding of how to even go about modelling a game that came in pretty quickly.

And in fact, Samuels checkers for program talked about evaluation functional learning very quickly because you could not go to the very end you always had to figure out what to do in the middle and the machine idea of machine learning came very quickly. But then the other ideas stick took some time to come in, for example, alpha beta search came only in 1966, it took about 10 15 years for somebody to recognize that you can actually keep bounds and so reduce their amount of search that we need to do.

Then the idea of transposition table became very important in chess and in lot of games. For example, I make move 1 you make move 2 I make move 3 and you make move 4. That is possible and equally possible, often impossible is that I make move 3, you make move 1, move 2 I make move 1, you make move 4 you will get to the same point, like I move this pawn you move that this pawn I move this pawn you move this pawn.

We do it in the reverse order, I move that 1 first, you move that 1 first I move this pawn second you move this pawn second you will get to the same state. So in games, and I can actually go back and forth, you know, I moved my, you know, knight and I moved back, I moved my knight and you moved it back, and so on, so forth. So these kinds of circle cycles are actually extremely common in a game. And we know that when we do search when we do research, then for each path for reaching a node, we are creating a new node.

For each path through each aboard position, we are creating a new node. And that is not very good. It is not very scalable. So the idea that we can store some memory and do some duplicate detection came in 67. And in the context of games that was called transposition tables. So basically, if 2 board positions are the same, let us not create a new node for it. Let us just you know, maintain the evaluation function and the best action to do there separately.

Then the idea of identity of deepening came and it took another 8 years to commit, so then iterative deepening happens, so you will go 1 step then you will go 2 Step search and you will do 3 steps search and you will reorder your children based on the search that you read in the previous iteration. Then many other ideas started to come in the 80s. Some ideas were, you know, the idea of endgame databases, opening databases, some ideas that you know, one move maybe so good that you can always look at it singular extensions.

Then, when bigger supercomputer started to happen then the idea of search can happen in parallel. We do not have to do it on 1 CPU we can do it on a supercomputer etc. So when all such ideas started to come together, the chess player started to become better and better and, in fact, the deep blue player is really if you think about it,

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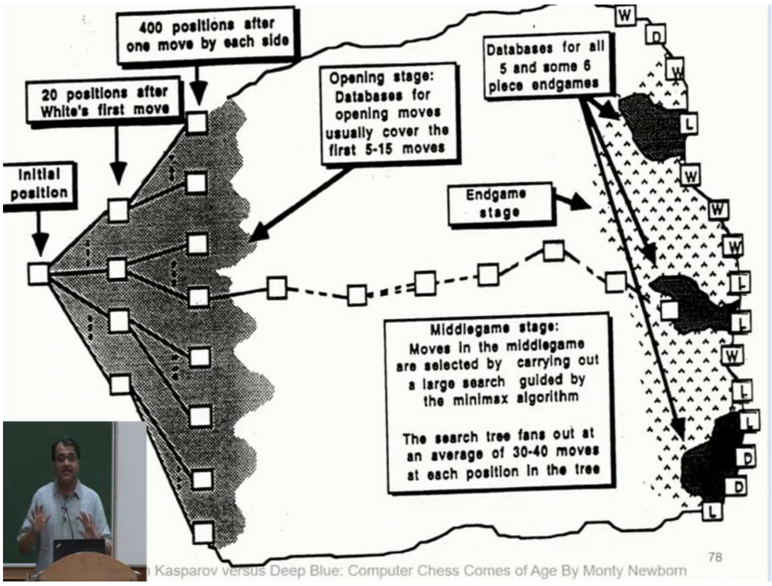
400 positions after one move by each side
20 positions after White's first move
Initial position
Opening stage: Databases for opening moves usually cover the first 5-15 moves
Databases for all 5 and some 6 piece endgames
Endgame stage
Middlegame stage: Moves in the middlegame are selected by carrying out a large search guided by the minimax algorithm
The search tree fans out at an average of 30-40 moves at each position in the tree
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n Kasparov versus Deep Blue: Computer Chess Comes of Age By Monty Newborn

It is some combination of. So initially, it would do an opening database. So the for the first 20 each positions, it sort of knows what to do. There is a few strategies that it will follow and will follow those strategies, It may it knows what moves to do. And based on what you do, it does not have to do search it sort of knows what to do. These are best practices in the field of chess you sort of know how the openings work. Towards the very end, actually, you can pre compute all databases, all possible games.

So let us say all possible games of 5 and 6 pieces. That is not a large number. Let us say I just think about I have a knight and king you have a bishop and king and upon let us say, you know, we randomly place them who wins. That is one ending game database. I randomly place them differently. Let us say I have another ending game. And I say I have 2 pawns and a king, you have a king and a queen. Let us see who wins.

So you when the game is at the very end, you can completely search. You do not need evaluation function at that time you have been completely search the game, because now your number of steps is not very much and so then you completely search if you can figure out who is going to win. So now it is like this that in the beginning, I know what to do sort of, in the end, I know what to do sort of I have pre computed it, I have memorized it, I have stored it in my databases in the opening database and in the end database.

What do I do in the middle is actually really, really complicated. Because what do I do in the middle there so many different kinds of middle positions, and the game is really far away to finish so it is like I am talking about a lot of look ahead and lot of starting points, I cannot store that in a database. There people use all the tricks that you had minimax alpha beta pruning, evaluation function, transposition table, I iterative deepening, singular extension, this that India, everything. So the really in practice, chess got divided into 3 steps.

The openings stage the middle stage and the end stage. The opening stage was clear what to do the end stage was pre computer and clear what to do. The Magic happened in the middle stage. And as you think a little bit you realize that this phenomenon is actually really valued. Valuable for people also say you are you are in a race. Just think about it just say let us say we are talking about a 2 kilometre race or a marathon or a half marathon or something like that.

When the buzzer goes and you start you have a lot of excitement. You will not have energy why is just starting out you know there is passion I want to finish this I want to win this whatever it is. Now when you see the finish line some distance away then you put all your effort into it. You say that is that is not end I have to go full throttle had to somehow get there as fast as I can you get motivation to get there.

In the middle is what differentiates the successful from the not, in my opinion. Because in the middle, it is very hard to maintain motivation there is no end in sight. You have been running for a long time, you do not know how much you have run, you do not know whether you are going to make it or not. There are lots of questions. There is so much confusion, there is so much insecurity.

That is when you need the maximum amount of intelligence. You need to somehow say we will keep going. At least in marathon, you know which direction you have to go. Suppose you did not know where the goal is. Let us say you did not know where Taj Mahal is you are just doing random work and you want to eventually find Taj Mahal and it is possible. This is how many of these games are you are to finally when you do not know where the winners and so when you started out from home you said, I will go in that direction.

I will definitely find Taj Mahal If you will start looking at Taj Mahal and Taj Mahal is you know, you can start to see it you sort of know I am going in the right direction. Now if I go here, I will probably reach Taj Mahal, now you have newfound motivation. In the middle, when you have come from your home a long way, there is no Taj Mahal you do not know where you should be going in this direction or that direction.

That is where the most intelligence is needed. So in life, think about it when you think that the going is getting tough when you think that you do not have an end in sight. When you think that you know, when you ask questions of whether you are doing the right thing or not, you are in the middle game stage. And taking the right actions in the middle game is what separates a better and more intelligent person or thing from the less because in the opening game.

Everybody’s using the opening game database in the end game everybody's using the end game database. It is only in the middle, you have to do search of the thing you are the evaluation function you have to have learned from experience that is where you figure out whether you are a good player or not a very good place. So always keep this in mind.

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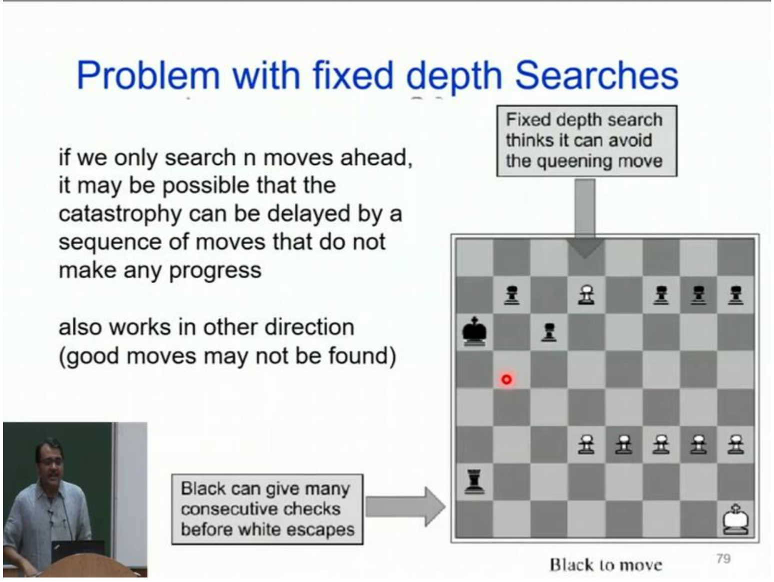

Problem with fixed depth Searches

if we only search n moves ahead, it may be possible that the catastrophy can be delayed by a sequence of moves that do not make any progress

also works in other direction (good moves may not be found)

Fixed depth search thinks it can avoid the queening move

Black can give many consecutive checks before white escapes

Black to move

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Let us see some problems that happen when we do this middle game search when we do this minimax search one of the problems with depth first fixed depths search. So, we are always saying we will go to 8 plays or I will go to 6 plays I will go to 10 plays I will stop. Now, there is a problem there. The problem is that when we are only looking at and moves ahead, it is possible that we are not able to observe catastrophic that is going to happen just one move later or just 2 moves later.

It is possible that you know, we think for example, in this example, black things. Black can give many consecutive checks before white escapes. So black things yes. I can kill the king of the white but it cannot if it searches further it will realize that the white will be able to escape. So, therefore, this whole plan of trying to give checks to the king is not very good, but it will not know because it is only searching till a certain depth.

So, it happens in both directions a move may look good, because I have looked at only a limited amount of time, and then it may turn out to be bad or a move may look bad, but if I had looked a little longer, I would have found that yes, I actually was able to you know, do check and mate or whatever.

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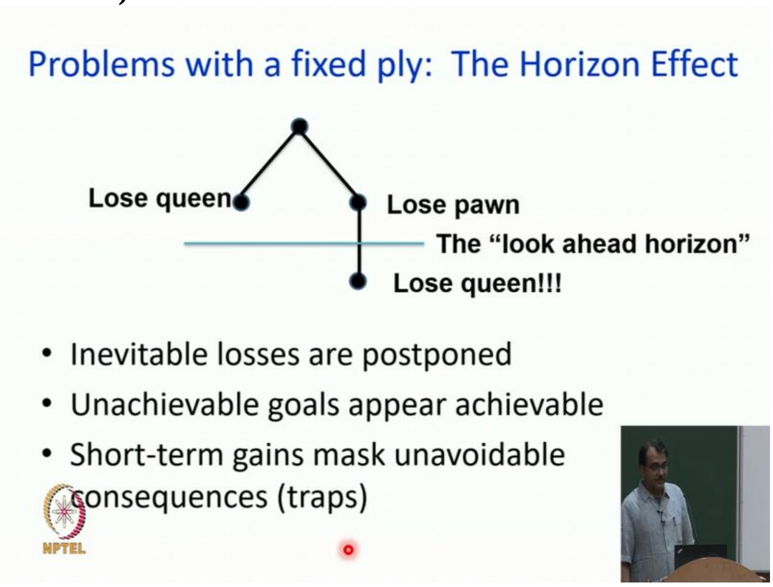

Problems with a fixed ply: The Horizon Effect

Lose queen

Lose pawn

The "look ahead horizon"

Lose queen!!!

- Inevitable losses are postponed
- Unachievable goals appear achievable
- Short-term gains mask unavoidable consequences (traps)

This is called the horizon effect. For example, in this case, if I do one action, I lose the queen. If I do another action, I lose the pawn until blue line until the cut off, but if I play a further I lose the queen. So which action should I do left or right left action I should do the left action I should just let the queen go but and save the pawn but I only search till the blue line left depth so I do the right action and when I do the right action I end up also losing the queen later in fact you will also recognize.

It another level of intelligence between people is how far they are able to look and think, you know, we have in India concept called dual they see somebody who is able to look really far into the future. Now, I am not talking about astrologers, somebody is and able to anticipate that if I make this action, this person will get unhappy, they may do these kinds of things that will make that person unhappy, that person may do some things which will really hurt me for example.

And this long chain of how what the consequences are going to be we normally are not able to think about but some people are able to think about that is what movies are made of. And so how far you are able to look into the future determines how in how intelligent you are. So, this is called horizon effect that how far you are able to look into the future and therefore, what action you do and so, what can you do I mean of course, horizon effect will always happen, because we are always going to search to a very specific depth.

But how can we mitigate this what can we do to reduce the effect of horizon effect? Any suggestions this is at this point algorithm design heuristic design, what would you do? If there was if you wanted to reduce the trouble that you will get or reduce the effect of horizon effect single extension what is singular extension? So, that is not called single extension but that is called secondary research what is your name? Shine, Shine says use the wrong term but Shine Search further down the selected part.

That is called secondary search. It is all sort of saying, look, I think this is the good path up to this depth. But maybe it is not. Let me verify it. How do I verify it, I just play the game a little longer from that point onwards, just develop that particular path. And if that particular path still looks good, then we if that particular path suddenly starts to look bad, then we was something was going go wrong. I have figured out that it is going to go along, let me backtrack and you know, do something else figured out a different plan of action. So that is called secondary search.

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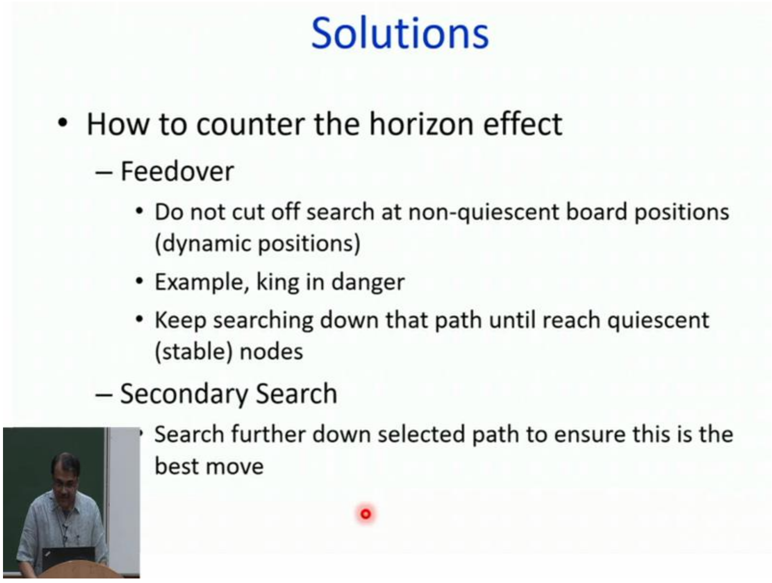

Solutions

- How to counter the horizon effect
  - Feedover
    - Do not cut off search at non-quiescent board positions (dynamic positions)
    - Example, king in danger
    - Keep searching down that path until reach quiescent (stable) nodes
  - Secondary Search
    - Search further down selected path to ensure this is the best move

There is another search, which is called quiescent search. Basically, what it says is that some more positions are 2 dynamic, like I have just given check. I do not know if the king is going save itself or not. I do not know whether it is a very complicated world position because I do not know what has happened in I have I have come to some level of stability and I have not.

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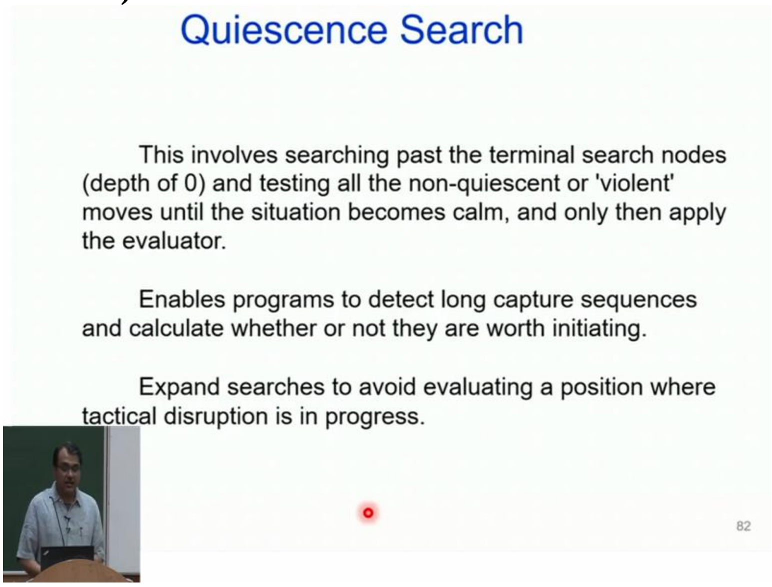

Quiescence Search

This involves searching past the terminal search nodes (depth of 0) and testing all the non-quiescent or 'violent' moves until the situation becomes calm, and only then apply the evaluator.

Enables programs to detect long capture sequences and calculate whether or not they are worth initiating.

Expand searches to avoid evaluating a position where tactical disruption is in progress.

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So, this level of stability in the context of game playing is called quiescent. So, I have a secondary procedure which figures out whether this board position will be called stable or not. And if the board position will not be called stable, I will not cut off there I will keep going until I get to a stable position so, I will do unequal searches. So, in one part of action, I may just go to search depth 6 in another part because it search 6 I get non question position I keep going and maybe search to depth 10 to get quiescent and position and then back it up.

So, as the slide says, This involves searching past the terminal state nodes and testing all the non quiescent of violent moves means that the board is unstable until the situation becomes calm, and only then apply the evaluator so you do not have a fixed depth you have a variable depth based on whether your cut off is at a quiescent position or not. So this enables programs to detect long capture sequences and calculates whether or not they are worth initiating.

This expands just to avoid evaluating a position where tactical disruption is in progress. Where lots of things are happening I am killing you, your pawn, you are killing my knight. I am killing a bishop blah, blah, blah. And then there are many, many other refinements.

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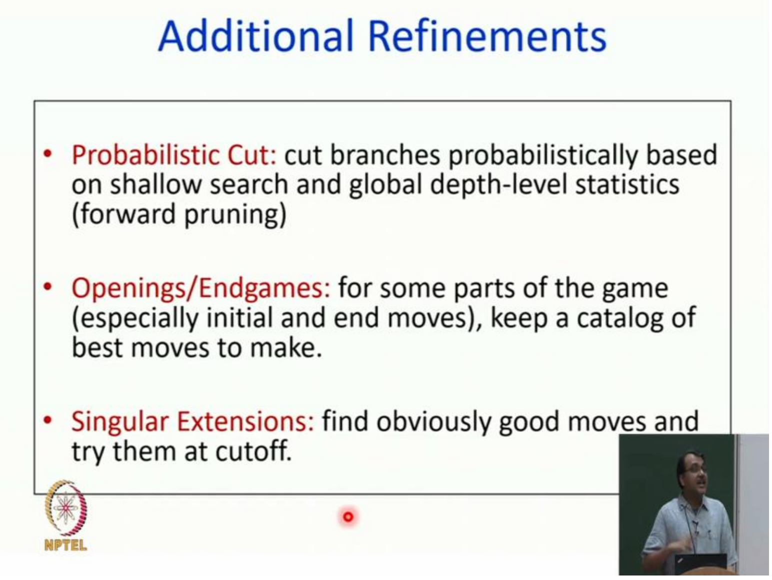

Additional Refinements

- Probabilistic Cut: cut branches probabilistically based on shallow search and global depth-level statistics (forward pruning)
- Openings/Endgames: for some parts of the game (especially initial and end moves), keep a catalog of best moves to make.
- Singular Extensions: find obviously good moves and try them at cutoff.

So, in alpha beta pruning, we are only able to clone if it is guaranteed to be suboptimal, but this guarantee is too strong the word. So we probabilistic probabilistically cut it is guaranteed, but alpha beta is sort of in a bound in a region there is a very small band where this might be a good optimal move. Let me just probabilistic a little cut it nevertheless so that is called probabilistic that then you have opening databases and end game databases which I already talked about.

There is something called singular extensions where there are some obviously good moves. And you just maintain those obviously good moves, and then you apply them at photos. So many, many such ideas got developed in the field of chess. And a lot of this work was happening at IBM at the time, because IBM was really interested in, you know, making chess player that beats humans to showcase its strength and power position in AI.

In fact, if you could look at traditionally from the 50s, up to the 90s, and even until the 20th, or 2000s, and you know, early 2011 12, when Watson happened, IBM has consistently come up with big demonstrations, which have shown its power and its, you know, ability in artificial intelligence in the very recent times, Google and Facebook and so on, so forth, have now started to come up with really interesting AI technologies. For example, deep minded go player, but for big demonstrations typically, you know, IBM has done more than most.

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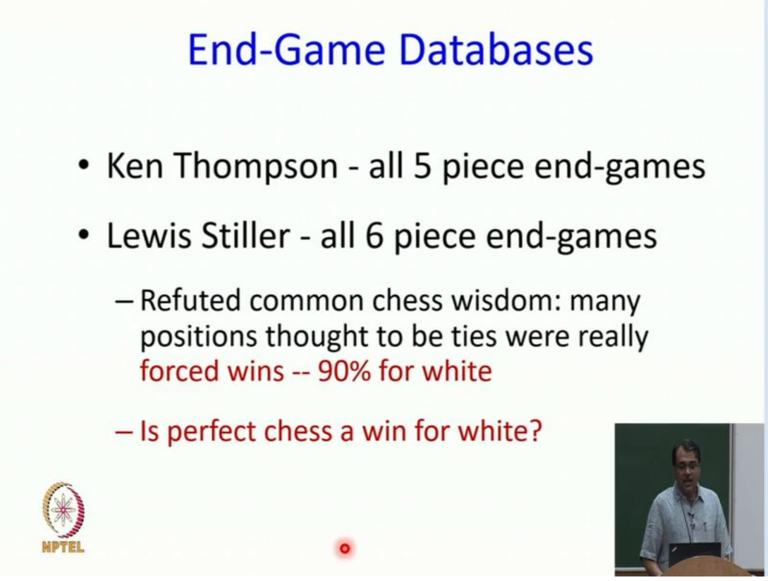

End-Game Databases

- Ken Thompson - all 5 piece end-games
- Lewis Stiller - all 6 piece end-games
  - Refuted common chess wisdom: many positions thought to be ties were really forced wins -- 90% for white
  - Is perfect chess a win for white?

Let me talk a little bit about endgame database so somebody came up with all 5 piece and game databases done did the full minimax search at that point figured out who wins. Similarly, Lewis Stiller did all the 6 piece and game databases. And in fact, what Lewis Stiller found that if you search long enough, if you are white, you can force black to lose 90% of the time. 90% of the end games that came up in game play, even though they may have been drawn in actual game were wins for white.

And that came up with the question is perfect chess win for white? We do not know the answer to this question. We have not been able to prove either way, but it is possible that if the universe started playing the game of chess, and you know used all its atoms to play the game of perfect chess, we may end up with the answer that, if we just play perfectly, white will always win. We do not know that,

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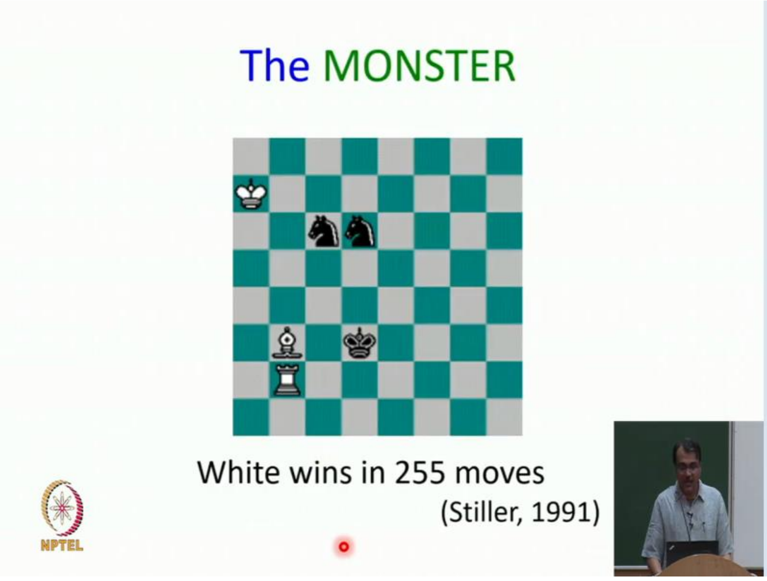

The MONSTER

White wins in 255 moves

(Stiller, 1991)

Here is what is called the monster and game in this monster and gain they are 6 pieces 3 of white 3 of black and it was considered to be a draw, I believe, but people showed that if you search long enough in particular 255 plays then white will can force away so no humans may not have been able to even get to this 255 long move, play sequence. So they may have done a draw but when you use the machine.

You figure out no this particular game position takes 255 moves worldwide wins. And many such positions exist. So, summing up, they have been a lot of deterministic games where we have spent some of the todays lecture on chess. Some of the ideas are also valid in many other games. So we will stop here. Thanks