The Society of Shogi
- A research agenda -

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Abstract

In this paper I will present my ideas about how to implement Marvin Minsky's *Society of Mind* theory in a game-playing domain, specifically shogi (Japanese chess). The following concepts play an important role in Minsky's theory: Agents, K-lines, nemes and nomes, frames, difference-engines, censors and suppressors, A-brains and B-brains, connection lines, types of learning and mental managers. In this paper, ideas are presented about how to link these concepts to concepts in shogi. To make a Society of Shogi, three important agencies must be implemented: a recognition agency, a lookahead agency and a learning agency. Ideas for implementing these three types of agencies are also presented.

Keywords: Society of Mind, Marvin Minsky, Game playing, Society of Shogi

1 Introduction

Marvin Minsky's *Society of Mind* [2] is an inspiring theory about human cognition. Unlike other cognitive theories, which limit themselves to partial cognitive behavior, it gives a general theory about the workings of the human mind. Minsky sees the mind as a large number of specialized cognitive processes, each performing some type of function. The most simple type of cognitive process is performed by an *agent* and the term *agency* is used to describe societies of agents that perform more complex functions.

Despite the popularity of Minsky's book, there seem to have been few attempts to implement his theory. One difficulty is that Minsky presents his theory in a large number of small chapters, each dealing with a small part of the theory and at a variety of levels. Furthermore, the theory is so diverse that it seems difficult to apply to real-world problems. Real-world problems require the implementation of a large number of agents to represent common sense knowledge. Only after this, it is possible to think of agents and agencies that deal with the problem itself.

The problem of applying a new theory to a real-world situation has been an issue in Artificial Intelligence for a long time. A common idea is to first apply the theory to a simplified problem. Games and puzzles have been used as a testbed for AI theories in the past and it seems a good idea to use a game as a test domain for Minsky's theory of human cognition. In this paper, a research agenda will be given for implementing Minsky's theory for the domain of *shogi* (Japanese chess).

In Section 2, the important concepts of Minsky's theory will be explained. In Section 3 it will be explained how these concepts can be interpreted in the domain of a game, in particular shogi. To build a *Society of Shogi*, three agencies need to be implemented: a recognition agency, a lookahead agency and a learning agency. Ideas for implementing these three agencies will be given in Section 4. Finally, in Section 5 the conclusions of this research agenda will be given.

2 The Society of Mind

As pointed out in Section 1, Minsky's *Society of Mind* is presented as a large number of small chapters, each highlighting a fraction of the theory. This is a very inspiring read, as each chapter seems to give some precious insight into the workings of the human mind. As an unfortunate side-effect, after finishing the book, it feels like one is ready to go, but it is very hard to decide where to start. Therefore, instead of using Minsky's original text, in this section I will mainly use the outline of Push Singh [3], who gives an explanation of the important concepts of Minsky's theory. The main parts of the theory are *agents*, *agencies*, *problem solving*, *communication* and *growth*. These will now be explained in detail.

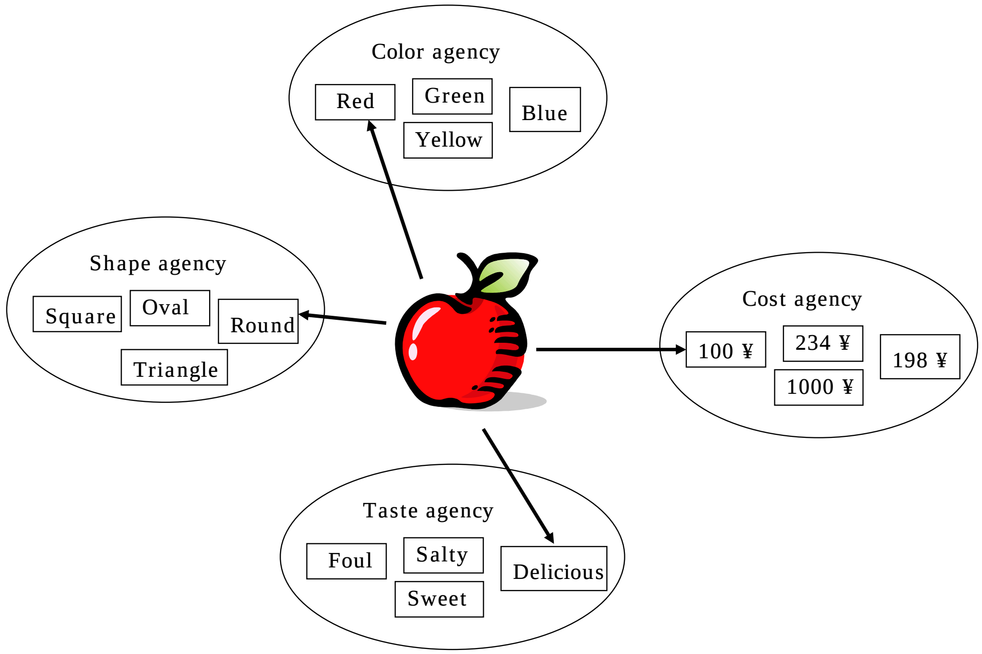

Figure 1: Small part of an apple polyneme

2.1 Agents

Minsky defines an agent as: "Any part or process of the mind that by itself is simple enough to understand" [2]. It is important to realize that the cognitive processing units in the brain need to be simple, in the order of agents recognizing color and shapes. Complicated behavior is the result of the interaction between groups of simple agents. Minsky describes a number of ways in which such an interaction can take place: *K-lines*, *Nemes* and *Nomes*.

K-lines are used to turn on a particular set of agents. Agents can have many connections, so activating a K-line can lead to an avalanche of activations of other agents. A K-line reactivates a previous mental state based on similarities between the current situation and a situation previously encountered. "K-lines cause a Society of Mind to enter a particular remembered configuration of agents, one that formed a useful society in the past" [3].

Two general classes of K-lines are *Nemes* and *Nomes*. Nemes are concerned with representing aspects of the world, while nomes control how those representations are manipulated. Nemes are produced by learning from experience. Examples of nemes are *polynemes* and *micronemes*. Polynemes invoke partial states in multiple agencies, where each agency is concerned with representing some different aspect of a thing. For example, seeing an apple arouses an 'apple-polyneme' that invokes properties in the color agency ('red'), shape agency ('roundish'), taste agency ('delicious'), cost agency ('100 Yen') and so on (see Figure 1). It is important that 'understanding' is not done with a single representation, but distributed among a large number of property agencies.

Micronemes are used to refer to aspects of a situation that are difficult to attach to any particular thing. Feelings like 'scared' and 'happy' are difficult to attach to a particular situation and therefore need to be controlled at a relatively low level using micronemes.

As said, nomes control how representations are manipulated. Examples of nomes are *isonomes*, *pronomes* and *paranomes*. Isonomes are a signal or pathway in the brain that has similar effects on several different agencies. For example, an isonome can make different agencies begin training a new long-term K-line or cause them to imagine the consequences of taking a certain action. Pronomes are isonomes that control the use of short-term memory. A pronome is often associated with a specific role in a larger situation or event, such as the actor, location or time.

Paranomes are sets of pronomes linked to each other so that assignments or changes made by one pronome to some representations produce corresponding assignments or changes by the other pronomes to related representations. An example of such behavior is the possibility to update a scene using both a 'body-centered' coordinate system and a 'third-person' coordinate system.

2.2 Agencies

The description in Section 2.1 is about activating agents and agencies, but does not address the problem of how to combine simple agents into larger agencies that can do more complex things. Minsky uses *frames* as a way to construct agencies. Frames are a form of knowledge representation concerned with representing a thing and all the other things or properties that relate to it in a certain way. Simple frames can be built from sets of pronomes that control the attachments to the slots of the frame.

A thing can be described by using a collection of frames where each frame describes the thing from a certain perspective. *Frame-arrays* are collections of frames that have slots or pronomes in common. By sharing slots, it is possible to switch to a different frame if the initial frame is inadequate for solving some problem or representing some situation.

Transframes represent events and all of the entities that were involved with or related to the event. A transframe can have slots for representing the origin and destination of a change, what caused a certain event and the motivation behind an event. The transframe representation is central to everyday thinking.

Other frames that Minsky describes include story-frames that represent structured collections or related events and picture-frames that represent the spatial layout of objects within scenes. It is expected that many different types of frames are needed to represent and organize the world and the cognitive processes.

2.3 Problem solving

Minsky argues that there may be many different methods that societies of agents use to solve problems. He suggests the following ways to organize problem solving societies: *Difference-engines*, *Censors and suppressors* and *A-brains and B-brains*.

Difference-engines are used to reduce or eliminate the important differences between the current state and some desired state. First, the differences between the current state and desired state need to be recognized. Then K-lines can be used to reduce each difference by invoking suitable solution methods. The problem with difference-engines is that there is no single way to compare different representations, so there is no single mechanism for building difference-engines.

No method of problem solving will always work, so in addition to knowledge about problem solving methods, we also have much knowledge about how to avoid the most common bugs and pitfalls with those methods. Minsky calls this *negative expertise*. During the problem solving process, this is embodied in the form of censor and suppressor agents. Censors suppress the mental activity that precede unproductive or dangerous actions, while suppressors suppress those unproductive or dangerous actions themselves.

Some types of unproductive mental activity are not specific to any particular method, such as 'looping'. Minsky uses the notion of the 'B-brain' whose job is not to think about the outside world, but rather to think about the world inside the mind (the 'A-brain'). In this way, the B-brain can notice the errors and correct them.

2.4 Communication

Agents are very simple processes that need to interact to generate complex behavior. However, because they are so simple, agents know only very little about how other agents work, so communication between agents can only be on a very simple level. Minsky describes the following ways in which agents can communicate: *K-lines*, *Connection lines*, *Internal language* and *Paranomes*.

K-lines are the most simple way of communication between agents: just arouse some other set of agents. For this type of communication it is not necessary for the sender agent to know how to express an idea in terms of the representations available to the recipient agent. Such information is stored in the intervening K-lines that resulted from successful past communication.

Many agents are not directly connected to each other but rather communicate via connection lines, buses or bundles of wires that transmit signals to other agents attached to the bus. These wires can be initially meaningless, but over time the individual wires begin to take on local significance, that is, they come to acquire dependable and repeatable 'meanings'.

For agencies that need to communicate more complex, structured descriptions of things, a more elaborate communication mechanism using internal language is necessary. If one agent wishes to convey a complex idea to another, it attempts to reconstruct the idea expressed in its own representational system by a sequence of frame retrieval and instantiation processes. For each of these operations there is an associated 'grammar-tactic' that produces words or signals that are sent to the recipient agent. The recipient agent then uses 'inversegrammar-tactics' to perform analogous construction operations, resulting in the different representations used by the recipient agent.

The most common method of communication is probably not to use communication at all. When paranomes are used, many different representations are updated simultaneously, so different agencies have different representations available at the same time and no communication is necessary.

2.5 Growth

Growth is very important in the society of mind. Mental societies are constructed over time and Minsky suggests that the trajectory of this process differs from person to person. He offers several potential mechanisms for growth.

In an infant mind, the first functional large-scale agencies are *protospecialists*. Protospecialists are highly evolved agencies that produce behaviors providing initial solutions to problems like locomotion, obtaining food and water and the like.

Predestined learning is the idea that complex behavior need not be fully pre-specified nor fully learned, but can result from a mixture of partial influences. Learning a language is an example of predestined learning, learning that develops enough internal and external constraints to more or less guarantee the final result.

Learning can take on different forms. For example, *accumulating* is remembering each example or experience as a separate case. *Uniframing* amounts to finding a general description that subsumes multiple examples. *Transframing* is forming an analogy or some other form of bridge between two representations. *Reformulation* is about finding new ways to describe existing knowledge.

An important type of learning is not so much about how to require the specific representations and processes needed to achieve some goal, but rather how to learn when a particular goal should be adopted and how it should be prioritized relative to other goals. Minsky suggests that we learn many of our goals through interactions with our 'attachment figures', special people in our lives, such as our parents, whom we respect. Praise and censure from our attachment figures result in 'goal learning' as opposed to 'skill learning'.

Another important learning mechanism is the development of *mental managers*. As a mind grows up, it acquires not only increasingly sophisticated models of its environment, but also builds increasingly sophisticated cognitive processes for making use of those models - knowledge about when and how to use knowledge.

Finally, the mind needs to develop in multiple stages where these stages can be regarded as training each other. The mind can be seen as the result of a sequence of teaching operations where at each stage there is a 'teacher' that teaches the 'student'. At the next stage, the student becomes the teacher, and so on.

3 The Society of Shogi

Playing shogi is a problem solving task and therefore the general concepts of the Society of Mind theory that were described in the previous section will correspond to concepts in shogi. In this section the connection between general cognitive concepts and concepts in the shogi problem solving domain will be presented.

3.1 Shogi Agents

The first thing that needs to be decided is what the primitive agents are in the domain of shogi. As I see it, the most primitive agents in any domain are the agents concerned with input (perception) and output (action). In the shogi domain, this would be agents concerned with recognizing where each piece is (input) and knowing what each piece can do (output). These agents are initialized in the starting position and updated with each move that is being played.

Starting from this, the most simple K-lines are the K-line that changes the internal representation of the location of a piece and the K-line that updates the squares that pieces can move to based on the changed position. More complicated K-lines could turn on the internal representation of a castle formation or the moves that are needed to move into a desired formation.

Nemes in shogi could be representations of certain common formation like *Yagura* and *Bogin attack*. A polyneme for *yagura* would have partial states in multiple agencies. For example, the *Recognize Castle* agency could be in the state 'S7g-G7h-G6g-B8h-K6i' (see Figure 2), the *Build Castle* agency would be in the state 'B7i-B4f-K7i-K8i' (see Figure 3), the moves that are still needed to complete the castle, the *Castle Weakness* agency could be in the state 'strong from the top, weak from the side' and so on. Micronemes could be used to refer to certain feelings regarding a shogi position like 'safe', 'passive', 'tight', 'dangerous' and so no. Micronemes don't sound important, but it is quite likely that the feelings about a position guide the behavior of players. Intuition by top players about the dangers of a position might be controlled by micronemes.

Nomes are used to control how representations are manipulated. For example, isonomes could be

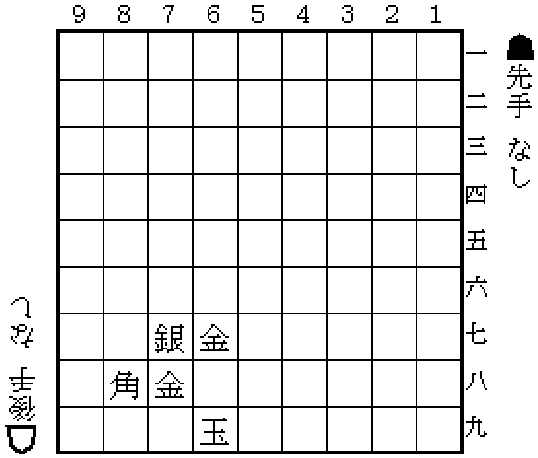

Figure 2: Example state of the *Recognize castle* agency

Build Castle	
1	B7i
2	B4f
3	K7i
4	K8h

Figure 3: Example state of the *Build castle* agency

used to train different agencies when a new castle is encountered. If first only the *yagura* is known and then the *anaguma* is encountered, the *Recognize castle*, *Build Castle* and *Castle Weakness* agencies have to be trained to deal with this new formation. Pronomes control short-term memory and could be used to store the plausible moves for oneself (play B7i here) while one thinks about the plausible moves for the opponent. Paranomes are used to make sure that when a plausible move for oneself is considered this not only updates the internal representation of the board position (bishop to 7i), but also the agencies that are concerned with recognizing ("the current partial *yagura* castle is 'S7g-G7h-G6g-B7i-K6i' "), building ("the current *yagura* building plan is 'B4f-K7i-K8i' ") and so on.

3.2 Shogi Agencies

Using frames to construct agencies can be effective in shogi as well. For example, a *yagura* frame could have slots for recognizing a *yagura* castle, the moves that should be played to build a *yagura*, ways to attack the yagura, and so on. Frame-arrays could be used to connect knowledge of the *yagura* from a defensive perspective with knowledge about the *yagura* from an attacking perspective (Figure 4). Note that all the arrows in the figure have two directions, indicating the importance of feedback between different agencies. I will return to the concept of feedback later.

Transframes could be used to store the motivation behind the moves that are being played, both by oneself and by the opponent. In this way, consistent long-term planning can be achieved, which is an important problem with current shogi playing programs.

3.3 Problem solving in Shogi

For problem solving in shogi, difference-engines are important. Good shogi players are able to move into desired positions in a flexible way, without rigidly following move sequences. Also, when a piece for some reason gets outplaced, for example a silver on 9e in the *yagura* opening, the moves 'S8f-S7g' to move the silver back to its optimal position can only be generated by a difference-engine. Difference-engines might be easier to build in games than in other domains because location and function are the only basic representations.

Censors and suppressors are also important in shogi. Good game players do not discard bad moves, they are unable to see them. The most common errors by professional players are not thinking about bad looking moves that are actually good or overlooking bad looking moves by the opponent that are actually good.

The difference between A-brains and B-brains can also play an important role in shogi. Losing a tempo in building a formation and returning to the same position are examples of problems that can be eliminated by using a B-brain to monitor the activity of the problem solving process.

3.4 Communication in Shogi

The importance of K-lines and paranomes for communication between agents has already been discussed in Section 3.1 which leaves the communication using connection lines and internal language.

Connection lines are a way to control signals between different agencies and without implementing those agencies there is not much that can be said about them. I believe that these connection lines can be used to control the *activation level* of agents. I have been unable to find anything about this in Minsky's theory, but I think that activation level is an important control mechanism to make a difference between important and less important con-

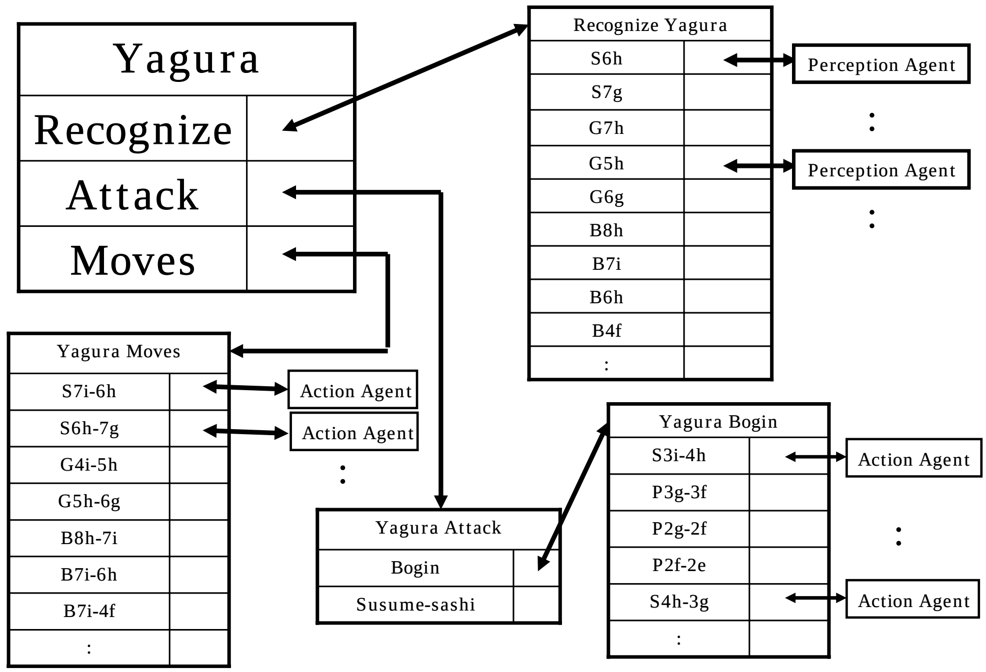

Figure 4: Example frames for the *yagura*

cepts during problem solving. For example, when one is about to lose a rook in shogi, saving this rook is usually more important than completing a castle formation.

As for internal language, I have a hard time imagining simple agents doing such complicated communication. I think internal language is important to give meaning to newly build agents, but I don't see how such internal language can be used for communication other than to the outside world. For example, jargon like *wall silver* could be the result of using internal representations that later need to be shared with other players and therefore need a name. However, it is possible that implementation of shogi agents will make communication by internal language necessary.

3.5 Growth in Shogi

Learning is of course very important in any society of agents. In shogi I don't see much use for protospecialist and predestined learning. These types of learning mainly seem to be involved with learning how to play a game. They might become important when a *Society of Game-playing* is built, i.e. a society of agents that can learn to play any game given a description of the rules.

Accumulating in shogi could be the storage in long-term memory of every game that has been played. It is well-known that top game players can remember the games they played for a very long time. Uniframing can be used to categorize a certain game as 'Static rook', 'Ranging rook', 'Anaguma' and so on. Transframing might be used to learn concepts like 'joining pawn attack' or 'dangling pawn' that can appear at different places on the board. An example of reformulation is the concept of wall silver.

To guide learning, the role of attachment figures is also important in games. Rather than one's parents like in most learning situations, the attachment figures in games are the top players, specifically the top players we admire because of their results or playing style.

The learning mechanism of mental managers is also very important in shogi. When to play the *Bogin attack* and under which circumstances this attack is not effective needs to be controlled by mental managers.

4 Building Shogi Agencies

Finally, I will give some more general ideas of how to build a Society of Shogi, i.e. which types of agents and agencies I think will be needed to result in proper shogi play. To play a game, three important processes (agencies) are needed: a *recognition*

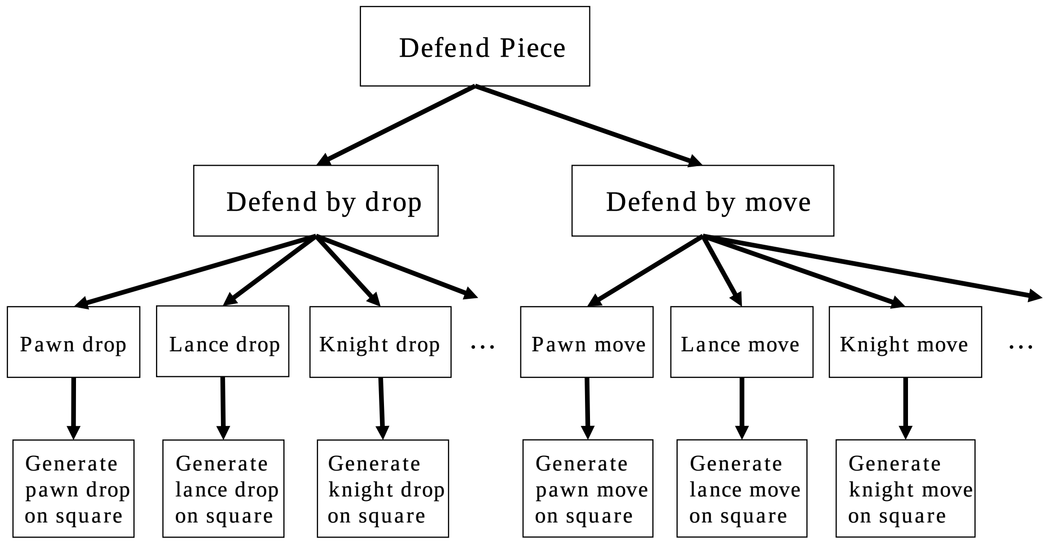

Figure 5: Part of a hierarchy to defend a piece

agency, a *lookahead* agency and a *learning* agency. I will now look at these three major agencies in a little more detail.

4.1 The Recognition Agency

The recognition agency has two major sub-agencies: a *Context recognition agency* and a *Evaluation agency*. The context recognition agency has agents to recognize the following:

- Strategy: static rook, ranging rook
- Castle: yagura, anaguma, mino, etc.
- Attack strategy: bogin, edge attack, etc.
- Piece attack: which pieces are in danger of being captured
- Current plan: trap piece, attack pinned piece, etc.
- Mood: attacking, defending, passive, active, etc.
- General aim: go for material or go for mate

The evaluation agency can have agents to evaluate the following:

- Material
- King danger
- Mobility
- King distance
- Forks, pins and ties
- Weak points like the head of the knight

Each of these agencies has to be a hierarchy which is connected through different levels with the primitive agents of piece location and piece movement. An example of a small part of such a hierarchy for defending a piece is given in Figure 5.

4.2 The Lookahead Agency

The lookahead agency also has to have two major sub-agencies: a *Move generator agency* and a *Search agency*. The move generator agency will be closely linked to the recognition agencies. Examples of move generator agents are:

- Capture piece
- Move attacked piece
- Defend attacked piece
- Attack king
- Play fork
- Attack pinned or tied piece
- Attack weak point
- Move piece closer to king

This is only a small example set. When looking at the move categorization in strong shogi programs like YSS [4] it is expected that many more will be needed.

The search agency will probably be the most complex one, as this is at the core of problem solving in games and human players don't use a single strategy for problem solving. First, it is important to attach some sort of priority to the moves that are being searched. This should be based on the activity level of the recognition agents that triggered the move generation.

Also, much of human problem solving is based on *satisficing*, i.e. confirming that the intended course of action was correct. Top game players spent a significant amount of their thinking time on checking if there is a problem with what they intend to play. In most cases there is no problem and they will play the move that they initially intended. The interesting and probably most difficult problem solving behavior occurs when a problem is detected. *Feedback* is very important for the problem solving process, but I have been unable to find a clear representation of feedback in Minsky's theory, despite the fact that the brain seems to be wired more backward than forward [1]. Feedback should change the activity levels of the recognizer agents and the move generator agents, giving other moves than the move that was initially intended a higher priority.

4.3 The Learning Agency

Learning is also expected to be a complex activity in the Society of Shogi. I think the main trigger for learning is overlooking or underestimating a move by a strong player (either the opponent or from game records). Overlooking a move, i.e. not generating the move at all, should trigger a learning process that creates new agents. Agents that create the move are of course necessary, but also recognizer agents need to be created to have the proper context (understanding) of how and when to generate the move.

Underestimating a move can be caused by a problem with the activity level of the agents involved in creating the move. If this activity level is too low, the move will only be considered for a little while or not considered at all. Learning in this case should be to increase the activity level of the agents connected with the move that was underestimated. However, it is possible that the activity level needs to be increased too much, resulting in strange behavior in similar situations. Therefore, it is also possible that new recognizer agents must be created to store the context of a move that was underestimated.

5 Conclusions

In this paper I have given the most important concepts of Marvin Minsky's *Society of Mind* theory and how these concepts can be translated to a game-playing domain, specifically shogi. I also have given some ideas about how to make a shogi program based on Minsky's theory.

I will now start to build the Society of Shogi based on the ideas outlined in this paper. Building agents and agencies is expected to be the most time consuming task, not because of the difficulty, but because of the number of agents that needs to be implemented. A more efficient approach might be to focus on the learning aspects of Minsky's theory and build a Society of Shogi that can learn without needing too many agents. However, unlike the interaction between different agents, Minsky's theory seems to lack details about the way agents learn. At this point, I will try to implement the basic recognizer and lookahead agencies and leave learning until higher level concepts are needed.

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