Shared concepts between complex systems and the game of Go

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Abstract

We developed complex systems playing the game of Go using specific concepts and methods. Due to the inherent complexity and to the riches of the game of Go, some concepts can be shared with other complex domains. We present links with domains such as Economy, Social Sciences, War simulation, Linguistic, Biology and Earth Sciences. Links with Economy are based on investment and decision making. Links with Social Sciences deal with the relative importance of social agents. War simulation uses strategic concepts of Go. Go provides Linguistic with two-dimensional representations. Biology and Computer Go deal with ontological problems. Earth Sciences and Computer Go give place to chaotic and complex behaviours.

Résumé

Nous avons développé des systèmes complexes jouant au Go en utilisant des concepts et des méthodes spécifiques. La complexité inhérente du jeu de Go et ses richesses permettent de généraliser ces concepts à d'autres domaines. Nous présentons des liens avec l'économie, les sciences sociales, la linguistique, la biologie et les sciences de la Terre. Les liens avec l'économie sont basés sur l'investissement et la prise de décision. Les liens avec les sciences sociales traitent de l'importance relative des agents sociaux. La simulation de la bataille utilise des concepts stratégiques présents au Go. Celui-ci fournit des représentations originales utilisables en lingistique. La biologie et le Go traitent de problèmes ontologiques. Les sciences de la Terre et le Go donnent lieu à des comportements complexes et chaotiques.

1 Introduction

We both have achieved complex systems playing an entire game of Go[1] (Gogol [Cazenave 1994] and Indigo [Bouzy 1995]) using specific concepts and methods. The purpose of this paper is to show various links between our work and other complex domains.

In section 2, we begin making analogies between Go and domains studying human interactions (Economy, Social Sciences, War). In section 3, we continue showing interdependencies between Go and Linguistic. In sections 4 and 5, we follow by analogies with Biology and Earth sciences. Then, we conclude in section 6.

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[1] The game of Go is a very complex two-person, complete information game. Its complexity is high, there is an average of 180 possible moves, a game lasts about 300 moves. A position is hard to evaluate, and a good evaluation function needs a lot of knowledge. In comparison to Chess complexity (10^{43}), Go complexity(10^{172}) is approximatively higher by a factor 10^{130}

2 Society

In this section, we consider society as a complex system under three different points of view. We begin with an analogy between Computer Go and Economy, followed by analogies between Computer Go and Social Sciences as well as War simulation.

2.1 Economy

In Go, our systems use three levels of knowledge : strategic, tactic and operational knowledge. The strategy defines the goals to achieve and their relative importance. The tactic gives the short term and long term effects of the action in term of goals achievement. The operational level is concerned with the moves achieving the different goals. The analogy with Economy lies in the way knowledge is used to make decisions : the strategy is the definition of the goals of an organisation, the tactic is the forecasting of the effects of the actions the organisation does, and the moves are the actions an organisation is able to do to change itself and its environment.

Modelling the benefits of an investment is an example of the potential use of such an analogy. In Go, the notion of investment can be represented by the number of stones that are invested in a group. Benefits of an investment is the number of points the group will count at the end of the game. Each stone costs one move, each move can be considered as a choice of investment. An investment is made using many criteria. The evaluation of each criterion can be viewed as an evaluation of reaching a goal in Go playing programs. The final multicriteria choice can be viewed as the selection of the move to play on the overall board using strategic knowledge on the importance of achieving each goal.

The reasoning of the Go programs which is described by three level of knowledge can be used to model and categorise the knowledge used by an organisation to make actions in its environment.

2.2 Social Sciences

In Go, the value of a stone is mainly given by its relations to its environment and not by the stone itself (on the contrary of Chess where the value of a piece is mainly related to the piece). During the game, each stone has a different value depending on its environment, and on its link with surrounding friend and enemy stones. Go players and programs group some set of stones together to form entities they call "groups". A group has many features, for example: territory (the number of points the group can give you at the end of the game), safety (determining to what degree the group belongs to you, its viability), flexibility (a group is flexible if it can achieve multiple goals).

An analogy with Social Sciences can be made when comparing a stone to an agent, and a group to an organisation. The size of the group is the size of the organisation, its territory is equivalent to the implantation of the organisation, safety and flexibility are the same concepts in both domains. The tools we developed can be used to forecast the evolution of a society when adding or removing agents. We do not have the laws describing the involvement of adding an agent to a society, but if a researcher in Social Sciences can provide such laws, we can use our tools to model the effects upon the society of its organisation.

2.3 War simulation

War, as well as Go is concerned with territory. Many concepts present in books on war find their equivalent in Go. For example "Dividing the enemy before attacking", or "Staying linked reinforces the position". Mao wrote about war practices which have their equivalent in Go : one often gives something in exchange for something else, but switching to other places keeps the initiative. This is the exact definition of the notion of Sente in Go. Go is particularly suited for war theories concerning guerrilla, which is the speciality of extreme oriental armies. Another interesting concept in Go is the concept of Seki : in a Seki situation, the first to attack loses. The theorisation of battle made with Computer Go, can be useful to improve strategies used in computer war simulations.

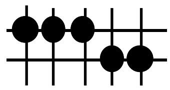
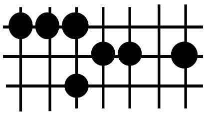
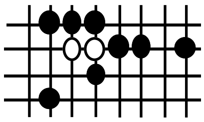
3 Linguistic

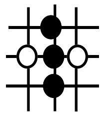
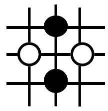
Human beings communicate mostly using Natural Language (NL). An obstacle in NL understanding and linguistic is the persistent reference to the spatial world. Spatial world has three dimensions although NL has only one dimension. We think that the study of the use of two-dimensional languages, can uncover interesting mechanisms of human cognition : their dimension (two) is nearer from the dimension of the spatial world (three) than NL's dimension is (one). Drawing, calligraphy and the game of Go are examples of such two-dimensional languages. This part addresses the links between the game of Go and classical languages. The links are communication, syntactic structure, Saussure's expression-meaning-reference tripole and complexity.

[Saussure 1916] already developed the idea that Chess was a communication between the two players. One can extend this idea to other games and particularly to the game of Go. In Go, the point is that the language in which the communication operates is two-dimensional and expresses itself on the board : one can group "stones" into "strings" and "strings" into "groups" that constitute the whole board. This process is exactly the same as the syntactic process of NL : one can group letters into words, words into sentences that constitute the whole text.

Saussure defines *expression* and *meaning* as two parts of the sign. Expression is the external part of the sign and meaning its internal part. *Reference* is defined later by successors of Saussure as the object, present in real world, referred by the sign. The same definitions stay in [Searle 1980].

A NL expression looks arbitrary in front of its meaning [Saussure 1916]. A NL expression can get several meanings and a meaning can get several expressions.

In Go, this is also true. A group (meaning) can get multiple appearances (expressions) on a Go board. A bag of empty intersections and stones on the board can be viewed as a Go word. And different Go words can have the same underlying semantic concept :  and  and  all refer to the \group/ concept. They are synonyms.

Similar words can have different semantics : learn and earn mean \learn/ and \earn/ respectively and \learn/ is different from \earn/. In Go,  and  are mostly identical (the black stone in the centre of the left pattern is not present in the right one) but one means \connection/ and the other one means \potential-connection/, that is semantically very different.

NL complexity is largely superior to Go complexity. NL complexity allows multiple interpretations of a text. Umberto Eco [Eco 1990] defines three categories : author's interpretation, text's interpretation and reader's interpretation. In Go, there is the same phenomenon : different possibilities to understand the Go board. The player is the author of its moves and the reader of opponent's moves. A player is able to approach the text's interpretation but he cannot have complete access to it because of the inherent complexity of Go.

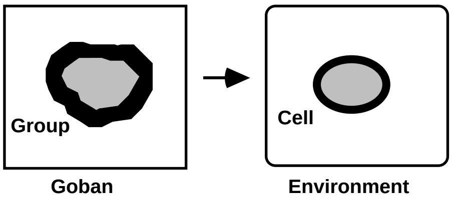
For instance, one player can think a group is dead and the other can think it is alive. If a player thinks a group is dead (resp. alive) he will play with a given (resp. other) strategy. To know if the opponent thinks the group is dead you can spend a move (asking a question). Then the opponent answers and uncovers his own interpretation. An implicit communication is born.

We have shown how Go can be an interesting subject of study for cognitive science and linguistic. It allows two-dimensional communication, it has grammatical structures, it is complex enough to enable multiple interpretations. However, it is different from NL, hence it gives new lights on the study of languages.

4 Biology

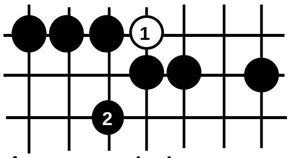
Biology faces several problems : ontology of living systems, autopoiesis [Varela 1989], explanation of shapes and immunity. This part shows that Go modelling encounters the same obstacles.

Ontology can be compared to the definition of *what* is the system, that is to say which parts of the environment are linked to define entities. Nobody knows how macromolecules group themselves into an autonomous cell. Nobody knows how cells group themselves into vegetals or animals. A living system must define itself by its difference with its environment. It has to get an *interior* and an *exterior*. In Go modelling, the same problem arises. It is very important to find what are the objects on a board. [Bouzy 1995] defines the objects recognition by using closed sets of mathematical morphology [Serra 1982]. The black (resp. white) groups on the board are the connex sets of the closeness of the set of black (resp. white) stones. Each group controls a set of intersections that is called its *interior*. Each group has a *boundary*. Other parts of the board are the *exterior* of the group. This way, a group is viewed as a cell that has a membrane as boundary, an interior and an exterior.



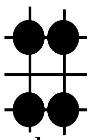
The group-cell analogy

Autopoiesis is concerned with viability. The viability of a system in an environment is due to its capacity to regenerate itself continually. Groups in Go must evolve during the game and survive to perturbations to be *viable*. Each group creates one move to survive when they are in danger. A group produces a stone that will be a part of the group in most cases as shown on figure below. After the white move at 1, creating a perturbation for the black group, the black group produces the black move at 2 to survive. This way, a group is a system that produces itself.



An autopoietic system

Another very important topic of interest both in biology and in Computer Go is the study of the shapes. No biological theory gives good explanations of the shape of living being. A shape theory should both be interested in the principles underlying the appearance of shapes and also in the use of these shapes in the life of the animal. Computer Go gives a strong theory of shapes, both for the underlying principles (a bamboo joint is interesting because it is a connection between stones) and for the use of these shapes (a bamboo joint is used to protect a group).



A Bamboo joint

The immunity system can be considered as a system acting to differentiate between what is part of him and what is not. Trying to eliminate what is alien, keeping what is friend. An interesting component of this system is its ability to memorise action to destroy enemies it has already encountered (this underlies the principle of vaccination). A learning Computer Go program [Cazenave 1994] does the same thing. When faced with an opponent group, it creates rules that aim to kill it. When achieving this goal, it memorises the rule enabling to kill the bad shape of the opponent and will reapply it each time it encounters again the same shape. It must make the difference between moves (or rules) killing the opponent and moves killing its own groups.

5 Earth Sciences

In the beginning of the century, D'Arcy Thomson has shown the interest of studying shapes of natural objects like mountains, seas, lakes, hills, passes and other complex geographic objects [Thomson 1917]. Recent successes of fractal geometry [Mandelbrot 1982] give some new models of their construction. Fractal structures can also emerge in Go positions [Yang & Yao 1991].

Complexity can emerge from simple laws acting on a big number of elements that are in interaction. Nature is full of complex systems : seas with millions of millions of drops of water, snow with millions of millions of flakes, clouds with millions of millions of droplets. Such systems get a chaotic behaviour that can be catastrophic as a soliton propagating through the whole ocean, avalanches of snow devastating a mountain, clouds giving rain or even the famous movement of a butterfly in New York producing a storm in Tokyo...

A Go board can also be interpreted in terms of interacting elements. Chaos may appear on a Go board when a small change (putting a stone) leads to very different global evaluations [Bouzy 1995].

The advantage of Go to study chaotic phenomenons, that are similar to real ones, is its intermediate complexity : it is complex enough to give place to chaotic behaviours but not too complex to be modelled in practice.

6 Conclusion

We have shown how studies on Go can be useful to other domains as different as Economy, Social Sciences, War simulation, Linguistic, Biology or Earth Sciences. This fact is due to the inherent complexity of Go which allows multiple links with other complex domains.

References

[Bouzy 1995] - Bouzy B. - Modélisation cognitive du joueur de Go - Thèse de l'Université Paris 6 - LAFORIA-IBP - 1995

[Cazenave 1994] - Cazenave T. - Système apprenant à jouer au Go - 2èmes Rencontres des jeunes chercheurs en IA, Marseille - 1994

[Eco 1990] - Eco U. - Les limites de l'interprétation - 1990

[Mandelbrot 1982] - Mandelbrot B. - The fractal geometry of Nature - San Francisco, Freeman - 1982

[Saussure 1916] - de Saussure F. - Cours de linguistique générale - 1916

[Searle 1980] - Searle J. - Meaning and expression - 1980

[Serra 1982] - Serra J. - Image Analysis and Mathematical Morphology - Academic Press - London - 1982

[Thomson 1917] - Thomson D'A.W. - On growth and Form - Cambridge University Press.

[Varela 1989] - Varela F. J. - Autonomie et connaissance, Essai sur le vivant - Seuil - 1989

[Yang & Yao 1991] - Yang Z.J., Yao J. - Cluster dimensionality in the game of Go - Physica A 176, pp. 447-453, North-Holland - 1991