Artificial Intelligence and Bridge

Bridge played by computer
at the highest level of human performance
has been solved 30 years ago.

Here is how…

The original French text : http://www.will-bridge.com/bridge/Bridge_IA.htm

Preface

The body of this article was published in 1984 in the leading French magazine "Le Bridgeur".
It presented the basic ideas of Philippe Pionchon that had led 2 years later to the creation of a software solving the whole problematic of bridge vs Artificial Intelligence (AI), considered unsolvable at that time.

More than 30 years later, the founding ideas exposed here remains valid:
no progress has been made since that time in the field of ***AI*** *applying to Bridge despite many attempts.*

However, it should be noted that in the 90s, several competing software packages were made and marketed in the US; in reality, no AI is applied as they use knowledge of the 4 hands or systematic application of algorithms or not necessarily adequate heuristics, thus inefficient.

Since then, various such software clash each year in a highly competitive World Computer-Bridge Championship. However, 30 years later, we must recognize these software are very far away from human performance or those demonstrated by the software of Philippe Pionchon in the 80s.

Today in France, chasing the trend of "Artificial Intelligence", taking advantage of the media craze created around the scientific concept of "neural networks", researches are launched in some universities but without real future in the opinion of Philippe Pionchon, for wanting to adapt to the field of "problem solving" the statistical techniques used in the field of "Form recognition", one commits a ***fundamental error both in method and in objective****.*

There are in fact, according to him, several forms of "Artificial Intelligence":
*- "**Digital AI**", based solely on calculation, without concern of "reproducing human behaviour" and without the ability "to explain" the solution found.*

This method is inspired by the biological metaphor of the neurons of human brain to constitute what it became commonly called "neural networks".
It is here, and thanks to their ability to "self-learning" statistical calculation, that these techniques use the term of "Artificial Intelligence".
*Very effective in some case, this method occurs for example in iterative error correction calculations of the "**deep learning**" to enrich the field of "Form recognition" where, based on the "**raw force**" of computers, it has demonstrated its great efficiency*

*- the "**analog AI**" is not based on complex calculations but is intended to simulate the process of human thinking (which is the fundamental objective of AI) based on the **logic** .*
This is the method normally used in the IA field of "Problem solving" where the context is very different from the "Pattern recognition" (information often incomplete).
Thanks to its theoretical investigations, this logical approach, necessarily implemented by experts in the field studied, is by definition likely to advance the object of its analysis, here the Bridge.
*It also has the immense advantage of providing an **explanation for the proposed solution** most of the time.*
This "explanation" gives it an indispensable educational interest in certain fields, notably that of the Bridge.

Digital AI and Analog IA

To avoid method errors in the use of AI, it may be interesting to emphasize the fundamental differences between "digital AI" and "analog AI".

*- The goal of "**digital AI**" is to simulate the biological functioning and organization of the human brain, the "neural networks":*
*thus in the computer, from **basic repetitive elements** , the "**patterns**", which the program itself will have highlighted in its process of form analysis for example, **parallel computing** functions simulate the functioning of the human brain in a sum of "**micro-**processes" and it is this metaphor which makes it say that it is "Artificial Intelligence" when it is equipped with machine learning method, more precisely **statistical self-learning**, allowing it to learn from examples.*

*To take an image, it is, if you will, a “**hardware approach**”, one could say, of the human structure, using the "raw force" of computers in domains with **complete information**.*

*This **essentially statistical** method makes some experts say that it is more of a “**forecasting intelligence**”, of predictive analysis working on the modelling of knowledge, that of "Artificial Intelligence" strictly speaking.*

No matter, the effectiveness of “digital AI” has recently been brilliantly demonstrated in the field of "Form recognition" or the “Image analysis": the power of growing computers doing wonders for dealing with "big data" far more effectively than can’t do the human brain.

*- in "**analog IA**" it's a different story, and the objectives are much more ambitious: the goal is to simulate human behaviour, not in its basic structure, but in its **logical operation**:*
so the machine becoming capable of reasoning by itself and learning from its experiences.

*This method is very complex because it requires an **expert analysis** of the field studied but it finds all its effectiveness in the treatment of the problems of "thinking with **incomplete information**": to reproduce the mental process of the thought, to deconstruct a goal of resolution in successive steps for to define a strategy, exactly like a bridge player do "at the table", by using, is the idea of Philippe Pionchon, on **meta-knowledge** and **modal logic**.*

*To maintain our image, it’s an approach of software “**macro-**process” particularly well suited to the field of thinking strategy games where it’s a question of planning an action.*

*Moreover, this method, which is close to human behaviour, has the immense advantage of being **pedagogical** and, by the theoretical research that it assumes on bridge game, it is moreover likely to advance the knowledge of this subject.*

*To summarize, analog AI is organized around **expertons** or "logical granules" (see below), as digital AI is organized into **patterns**, or "physical granules".*

Bridge application

For the subject that concerns us, this difference in approach is gigantic:
by its logical approach, the analog AI brings an indispensable educational

dimension that doesn't bring the digital IA, if nevertheless one day comes to demonstrate the effectiveness digital AI Bridge, which is still far from established despite all the means implemented.

Eventually the two fundamental questions are these:
*. is the **digital IA** method relevant in the field of "incomplete information problem solving"?*

*. and even if successful, **what interest** would it bring to the pedagogy and knowledge of this game?*

*It is thus the method of the "analog AI" that Philippe Pionchon had chosen to develop, and which allowed, in the 80s, a modest Tandy TRS80, to play with success the famous deals of **H. Kelsey** for example, corresponding to the best level of the human performance.*
The deemed unsolvable bridge card game was solved, even if this software was not completed to deserve commercial dissemination:
the method chosen had demonstrated, more than 30 years ago, its relevance and effectiveness with a machine of very low power and a very rudimentary machine language.

*It's these demonstrations on TRS80 in France that convinced **Robert Lattès**, mathematician of genius, scientific writer and former Bridge World Champion (he had been partner of **Bertrand Romanet**) then President of Paribas Technology, to invest in the creation of a company, Will-Bridge, intended to complete these works, adorn them with a commercial presentation and, of course, eliminate the bugs and shortcomings of the program, inevitable in a very complex software, developed in a primitive machine language and to which only a few years of work had been devoted.*

*But thanks to the success of improvised tests done by a former World Champion on deals corresponding **to the highest level of human performance**, the verdict was formal and could justify an industrial risk:*
the technological gap was crossed, the problem solved, the good method demonstrated… the future is beautiful.

The objectives of the AI applied to Bridge

Let's take things more simply.
In the field of "problem solving", to have an indispensable educational dimension, a genuine AI program must reproduce as faithfully as possible

human behaviour:

*- Playing with **hidden cards***

*- Being able to **explain**, on demand, for each bid made or card played, why they were chosen.*

In Bridge it is not a question of calculation but of analysis, of intelligence.
If one has "understood", one must be able to explain, and the reasoning exhibited by the machine then testifies to the quality of the game provided and its ability to demonstrate its overall understanding of the problem.

In terms of "problem solving", this justification is essential.

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Bridge: an area of "expertise" and not of "raw force"

In 2018 Will-Bridge (a French company founded in 1987 by Paribas, Club Med and the French Atomic Energy Commission to exploit **Philippe Pionchon's** work in Artificial Intelligence) is a world leader in Bridge online games.

This company has created significant advances in Artificial Intelligence.

What is Artificial Intelligence?

The **Artificial Intelligence** is a discipline that aims to simulate human behaviour in its collection activities, understanding or decision.

It is practiced in different fields: form recognition, voice recognition, language analysis, problem solving, etc ....

There are, according to Philippe Pionchon, several ways of treating this simulation according to the field treated and the objectives sought:

the **digital AI** and the **analog AI**.

With regard to the area of "*Problem solving*", which interests us here, the selected “Analog AI” is characterized by an original approach in the computer processing of the problems which consists, not as in a conventional system in describe *the resolution of the problem* , which requires knowing the algorithm of resolution, but to set up a computer structure allowing the computer to *solve itself the problem:*
this structure being in place, it will be enough then to ***describe the problem, and no longer solving the problem****.*

Expert Systems

This is the basic idea that gave birth to the "Expert Systems" intended to treat the problems known as "**Knowledge**".

Expert Systems are computer systems in which the knowledge of experts in each field has been collected, and who know how to treat this knowledge by using the computing power of a computer to study the **correlations** existing between the elements of this knowledge and draw conclusions, "**inferences**", which themselves complete this "Knowledge Base", etc ....

In many fields, the problematic of Knowledge arises in terms of correlations and inferences between the objects of this domain.

The exploitation of this Knowledge can even establish new inferences that will enrich this Knowledge in a process of **self-learning**.

In the treatment of this kind of non-algorithmic problem, or located in a non-deterministic universe, it is a question of using the computer no longer like "intelligent slave" obeying a procedural logic, but like a *generator of inferences* working from "**predicates**", that is, a *logic describing the problem.*

A true creation of Knowledge can then be produced by the machine within the limits of the rules of knowledge and facts that have been provided.

Expert Systems exist in various fields such as Medicine where the machine can create a real medical diagnosis, Geology where the work produced by the computer will be comparable to that which could produce a geologist expert, etc…etc ...

The interest of Bridge

In the field of "problem solving", two very different issues must be distinguished:

- the problems of "**Knowledge**"
- and the problems of "**Thinking**".

If the S.E. is adapted to handle the problems of knowledge, they are in priori powerless to deal, by themselves, the problems of "thinking" or requiring a **global understanding of a situation**.
Most of the time they constitute however the essential cog to reach a solution.

The problem of global understanding of a situation is extremely important in IA, the main thing doubtless.

It is the one for example which now arises in the development of the **autonomous vehicles** or more generally in **robotics** when it is a question of endowing the robot of a global understanding of the situation: the S.E. can be then coupled with a system of digital AI of form or voice recognition, and show itself very effective.

In the same order of idea, to solve the problem of the card playing in Bridge, we shall see farther how coupling a S.E. with a "simulation engine".

*In this respect, it is interesting to underline how Bridge, with its necessity of global understanding and with its three very different phases (**bidding, opening lead and card playing**) covers all aspects of the problem-solving domain and thus, constitutes a privileged ground in theoretical investigations.*

Bid and opening lead: Problems of Knowledge

Let's quickly solve the problem of opening lead very simple to solve since it is an algorithmic problem that presents no difficulty.

The bidding problem is more difficult to deal with because it implements a much broader and more complex knowledge. But thank goodness this is purely a **"knowledge problem**" and the "Expert Systems" are perfectly designed to deal with this kind of problem.

In addition, these systems have a **natural pedagogical capacity** and can very easily answer the questions:
" *Which bid do?* And " *Why this bid?* ".

This can very easily be explained in a few words.
An Expert System is composed of a "knowledge base", a "fact base" and an **inference engine** designed to bring these two bases together to study the correlations and deduce a conclusion.

- The " **knowledge base** " brings together the knowledge of the expert of the field studied, here the bidding system used.
This knowledge base is expressed in the form of very simple rules of the type: *"If A and B then C".*
For example: *"If I have a regular hand, 15-17 HCP and no 5th major, so I open 1NT"*.
These rules of knowledge can be written in bulk in the database, without a pre-established order, to be added or deleted at leisure, which is very practical.
A sort of “dynamic logic” in a way, very easily modifiable at will.

- The "**fact base**", for its part, brings together all the parameters of the problem.
This fact base contains the initial data and then grows as the inference engine creates new facts.
For example "A exists", "B exists" or "I have 12 HCP", "I have 6 spades", "The situation is forcing", etc ... etc ...
So if we ask "Why C?",
"C exists because A and B exist", or again:
"I open 1NT because I have 16 HCP, a regular hand and no 5th major".

*Expert systems are **naturally pedagogical** systems that deal very easily with **positive explanations**.*

The problem is complicated when it comes to "negative explanation", when asked "Why not C?".

An expert problem

In the 1970s, academic research was irretrievably on the **negative explanation problem**, a variant of "backward chaining".

The idea applied at the time was as follows:
"If C does not exist it is that in the rule x is A does not exist, either B does not exist, or none of the two exist."
If A and B are not known in the base of the facts, then we look in all the rules which conclude to A on the one hand, then to B on the other hand, if one of the premises, at least, is not verified.

For example if there is the rule "If E and F then A" and if we ask the question "why not A?", we look at whether we have either "not E" or "not F" or 2.etc ... then we do the same for all the rules that conclude in E and F, ... and so on.
. Idem for B.

By practicing this systematic backward chaining, we immediately understand that we quickly end up with a **combinatorial explosion**: this method is not the right method.
A "raw force" that does not involve expertise is ineffective.

Insoluble for an academic, this problem was very simple for an expert.

At the beginning of the 80's, Philippe Pionchon had the idea of doubling the engine of inferences of the expert system of a second engine, of "**inverse inferences**".

The idea was obvious since it corresponded very exactly to what happens at a bridge table, each player having to do two things:
- produce a bid (inference engine): "If A and B then C"
- decode the partner's bid (inverse inference engine):"C = A and B".
For example, if my partner opens 1NT, I deduce that he has a regular hand and 15-17 HCP without 5th major. "

The problem of the negative explanation is then solved very elegantly.
For example, suppose we have these 2 rules:
  ."If I have 5 spades and I have to make a no-forcing bid then I say 3S".
  ."If I have 5 spades and I have to make a forcing bid then I say 3D".

The inverse inferences engine gives:
   .3S = “5 spades, no-forcing bid”
   .3D = “5 spades, forcing bid”.
- Suppose that in the base of facts we have 5 spades and we must make a forcing bid: the correct bid is thus "3D".
- We decode this correct bid with the inverse inference engine:
3D = “5 spades, forcing bid”.

- If now we ask the question "Why not 3S?", we decode 3S:
3S = “5 spades, no forcing bid”.

The comparison of the two inverse inferences gives immediately:
"*3S would not be forcing*".

(If necessary we assign to each premise a coefficient of "precedence", if several rules conclude at 3D).

The negative explanation *is solved very simply by the* ***comparison of inverse inferences***.

Simulation closer to the human **logical** behaviour, allows to obtain interesting performances that can’t bring a treatment by "raw force". At Bridge the treatment of negative explanation is paramount, as is often the case in matters of any teaching.

The negative explanation must always precede the positive explanation.

It is indeed difficult to be heard of a student who wants to say 3S when you want to explain that the correct bid is 3D.
First you must explain that 3S is not correct so that the student is willing to listen to you: *"3S is not forcing, very well, but then what bid to make?".*

This precept applies to any field of teaching.

The "expertons": strategic variables

It is therefore remarkable to note the perfect match of the Expert Systems to the Bridge bid processing.

Let's look at this rule of opening:
"If I have a regular hand, 15-17 HCP and no 5th major then I open 1NT" rule in which we notice the presence of the variable "HCP".

By inventing this variable, **Milton Work** did not suspect that he was creating what Philippe Pionchon later called an "**experton**".

It is around these experts, true "magical variables", that the expert organizes his expertise and more relevant expertons are identified by the expert, more the Expert System will be concise and efficient.

It has been created many expertons of the genre "NT Playable", "Make a forcing bid", "Robber certain, slam possible", "Forcing situation", "Robber and no more", etc ...

These expertons are **strategic variables** around which the Will-Bridge Expert System has been built and which gives it its effectiveness.

It is interesting to note, once again, that this corresponds quite to the behaviour of the human player who, without knowing it, uses these variables unconsciously.

*Building an Expert System amounts to **creating expertons** and researching these expertons allows to enhance the knowledge and the pedagogy of the expertise area.*

The effectiveness of "expertons"

It is by using these expertons that the Expert System can for example **take initiatives** , "to invent" bids such as the "4th colour":
by decoding all the bids it could do in a situation, it finds that none is possible for questions such as "forcing/no-forcing", unguarded colour, hand strength or number of cards in a colour, therefore it lacks information to make the appropriate bid.

For example, if the "in NT playable" experton is not satisfied because one colour, it will be able to take of itself the initiative "**to invent**" the "**4th colour"**.

Just as a human player would do.

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The bidding and opening lead problems being settled, it had left to resolve the card play, much more complex and especially deemed insoluble in 1984 ...

Thinking Issues: Strategy games

Historically in the computer processing of strategy games, the first achievements of Artificial Intelligence (in the 70s) focused on **Chess**, which had the reputation of being a game much more difficult than Bridge.

While nothing had been done for Bridge, many individual Chess machines existed with great commercial success and the question that intrigued the journalists was then:

" *Why are there machines performing well at Chess, very complicated game, and not Bridge that is simpler?* "

The answer is: "Precisely ..." and constitutes the "**paradox of the difficulty**".

The paradox of difficulty

There are several important differences between the Chess game and the Bridge card game.
The main one comes from the fact that in Bridge there are **hidden elements** while at Chess everything is "on the table".

To play Chess, a machine does not have to be "smart", it just needs to know how to calculate and use its "raw force".

From a combinatorial point of view, the Chess game is infinitely larger than the bridge game.
It is so that we can say that **men will never be able to master this game**.

In other words, the complete and exhaustive analysis of a Chess situation can't be done by any expert in the world and it would be more accurate to say that in Chess **the computer plays badly but nobody realized it**.

Worst it is their poor quality of play that made their commercial success: if these machines had played at a high level, they would have been unsaleable because unusable.
In the same way that a tennis robot of very high level would be unusable for the common people, unable to return the ball.

At Chess, the machine having decided such movement during the game, no one is able to say if there is another movement superior to all the others.

If we except the end-game problems of the type "Mat in x moves" for example, we can say that **a chess game has no solution** and therefore the game produced by a machine is difficult to criticize.

We can only see *in fine* that the machine has played better, or worse, than his opponent, no more.
This impossibility of global apprehension is so true that, in a chess game, a player will choose such a movement simply because it is "*deemed good*" or because it "*allows a pleasant development*":
subsequent developments are too numerous to do the complete analysis.

Therefore, and it becomes paradoxical, it is much easier to make a machine that plays Chess since it amounts ***to submit a problem that nobody knows the solution!***

Bridge is simpler... so more complicated!

Playing card, you must "think"...
Being able to make a global analysis of the problem.
At the time, the problem was deemed insoluble.

Moreover, in order to deal with it, one must take probabilities into account, which is relatively easy for a machine, but above all work in **modal logic**, as mathematicians say, that is to say, to appeal to theories of possibilities, of fear, of necessity ... etc.

So many domains that are far from being mastered in AI.
But there is worse…

At Bridge, there is "obligation of result"

At Bridge most of the deals can be **easily analysed** afterwards, with open cards, by even low-level players.

The game produced by a machine is therefore easily open to criticism.
If at a given moment a card and only this card must be played, any player will see it: the machine must absolutely find it.
It has "**obligation of result**".

In conclusion, and here is the paradox, Chess, since the game is very complicated, when the machine plays badly nobody sees it, while because the bridge game is simpler, everyone can easily get account.

A machine has an "obligation of result" to Bridge that it does not have to Chess.

So how to treat this obligation of result?

The card playing problem

The card playing problem is very different from that of the bids, which gives Bridge an interest quite exceptional for the investigations in theoretical research of IA.

For the card play, it is not a knowledge problem as for the bidding, but an analysis problem, a thinking problem and, as explained below, a **"meta-knowledge" problem**.

In addition, this problem is quite complex because the play at NT is very different from the “play at the colour”.

- **At NT**, the play is often simpler because the absence of asset makes that everything happens in the same "mathematical space", as scientists say: colour manoeuvres, communication problems, safety plays, dangerous opponent prevents, etc.

The problem is often "**tactical**" in **handling cards** of a colour.

Thanks to a **dynamic analysis** of each of the colours simulating the human mental process, the machine can detect the characteristics of these colours: asymmetrical, oriented, subject to locks, etc ...
and to find for itself the appropriate behaviour-r according to the objectives and parameters provided.

- **In colour**, it is more a question of plan combinations, of **manipulations of colours**: the approach is more global, more "**strategic**".

The previous dynamic analysis is then completed by a **static analysis** of the structure of the known hands which, assisted by an **Expert System**, will detect the "**typed**" deals for which the game plan is trivial (double cut, inverted dummy, eliminating-hand placement, cumulative odds, etc ...) or, in other cases, will offer several game plans that the machine will explore, thus reproducing the human mental process.

*Finally, the problematic of the card play is to determine **against which configuration of enemy cards must be played**.*

*It is the **dynamic analysis**, completed by a **static analysis** feeding off an Expert System, which will place the enemy cards according to the detected context (possibility, necessity, security, fear, urgency, probability, etc ...) thanks to the exploitation of the "**meta-knowledge**" and which will propose the game plans to consider.*

It would be much too simplistic, according to Philippe Pionchon, to reduce the calculation of this configuration to a statistical treatment.

The basic idea: meta-knowledge

Meta-knowledge is the "knowledge of knowledge", that is, the knowledge we have about knowledge.

If, for example, you are asked if Mr. Smith has been President of the United States, it is a problem of knowledge.
If you have the knowledge, that is, if you have the President list, you can answer yes or no.

If now you are asked the question “Has Mrs. Smith been president of the United States?” you will immediately answer "no" while you do not have this list, because you know that no woman has been President of the United States.

Meta-knowledge is enough, you do **not need knowledge** to solve your problem.

This is typically an important part of the problem of the card play at Bridge.
Philippe Pionchon was interested in this game a bit by chance because this game presented the advantage of being relevant, readily criticized and easily modellable.

Nothing was worth the Bridge card play, **deemed insoluble at the time**, to put his theory to the test.

"The Bridge is, to my knowledge,
***the world's most scientific game**:*
*it uses all the fields of **modal logic***
and bridge players spend their time, without knowing it,
*to reason in **meta-knowledge**"*

he said before developing his basic idea: to build a theory of intelligent machines on a **meta-knowledge Expert System**.

Established inferences on meta-knowledge:
*is not this **the very definition of intelligence?***

Possibilities, necessity, fear, probabilities, that is what the bridge players’ daily life is like:

- “I do not know who has the King of clubs, but I know that East has passed by and has already shown 11 HCP: he does not have the King of clubs."

- “I do not know who has the King of clubs, but I know that if this King of clubs is on the right, I can’t win. Since my goal is to win, the King of clubs is on the left, by necessity.
I play so as if it was on the left.

If there is, I won.
If it is not there I lost but anyway I could not win: so, I did not lose anything."

- "I analyse that only a 4-0 distribution of the opposing trumps put my contract in danger. So, I think they are 4-0 and I look for a strategy that is also winning when they are 2-2 or 3-1."

Of course, the treatment of meta-knowledge if it allows in many cases to intelligently resolve the problem of hidden elements, is not enough but can be **supplemented** later by a simple calculation system where the machine finds itself the solution in other areas such as colour handling or the processing **of safety plays**.

- "I do not have the King of clubs.
Is there a colour handling that wins that King of clubs is indifferently to the right or left?"

The machine therefore places it both right and left, with the instruction of course to use it only once, and if the solution exists, it will find itself the proper colour handling ...

Just like, once again, would a human player do!

That was how the bidding, opening lead and card play problems were resolved now more than 30 years ago.

All for the best in the best of all worlds, what follow-up has been given to all these technological advances?

Premature

Thirty years ago, Artificial Intelligence was not fashionable unlike what is happening today.
Much worse, it was even at the time of a real taboo, a fad of scientists.
The difficulty of being heard is well summed up by this anecdote arrived at Philippe Pionchon at the end of the 80s.

The scientific journalists of the time were very interested in the small machines marketed to play Chess.

One of them, a well-known Chess specialist, asked him one day:
- *"A computer-Chess, when you play badly against it, is "destabilized" and starts to play badly too...*
What about it of your computer-Bridge? "

Philippe Pionchon first explained to him that in Chess the problem was very different.
In a Chess game, all the experts agree that there are 3 steps: the beginning of the game (where we "recite" the known shots), the mid-game (very delicate) and the end of the game where the few remaining pieces facilitate arboreal calculation.

The difficulty is to define when we go from one step to another, the famous "problem in the limits" that physicists are familiar with.

For each of these 3 steps, the software applies different strategies and a commonly accepted rule says that we go into second step as soon as we “castled”: for example at the beginning of the game, it is enough to prematurely castle so that the machine thinks itself in the second step and unknowingly advances its King in the centre of the chessboard!
Machine is not "destabilized".

- *"What's going on with my bridge machine?*
Listen, I do not know, but let's try ..."

So the journalist composed a problem and only gave to computer, the declarer, the South and North hands.
The journalist leads and a few tricks later, he badly payed on purpose offering a trick to declarer.
Computer cashed and said ... *"Thank you very much!"*

Everyone seemed delighted with this demonstration and Philippe Pionchon expected some flattering publications in the specialized press ...

Nothing happened.

Two years later it happened that Philippe Pionchon met this journalist again and asked him:
- *"Do you remember our essay 2 years ago?"*
What did you think?

The journalist then replied very interested:
- *"Yes, indeed, I remember it very well but, tell me, it happened 2 years ago,*

you can tell me now:
how did you do to cheat?"

It was **very necessary to wait** another 30 years ...

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