2017
3RD QUARTER
QUARTERLY COMMENTARY

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Ghost Moves

Wei Qi (圍棋) translates as "surrounding game." It is the oldest board game in continuous play in its original form, some 3,000-4,000 years old. Confucius wrote of the many benefits in developing the mind and spirit for those who study the game, and the Qing Dynasty[1] codified the game as one of the Four Accomplishments to be mastered by the elite class.[2]

The rules of the game are quite simple. Two players alternate placing black and white stones on a 19x19 grid. Once placed, the stones cannot move. Should one player surround an opposing stone, that stone is captured and removed from the board. The object of the game is to control more territory than your opponent. Placing stones together give them strength, making them harder to surround, whereas stones far apart can

1 1644-1912.
2 Along with calligraphy, painting and playing the lute.

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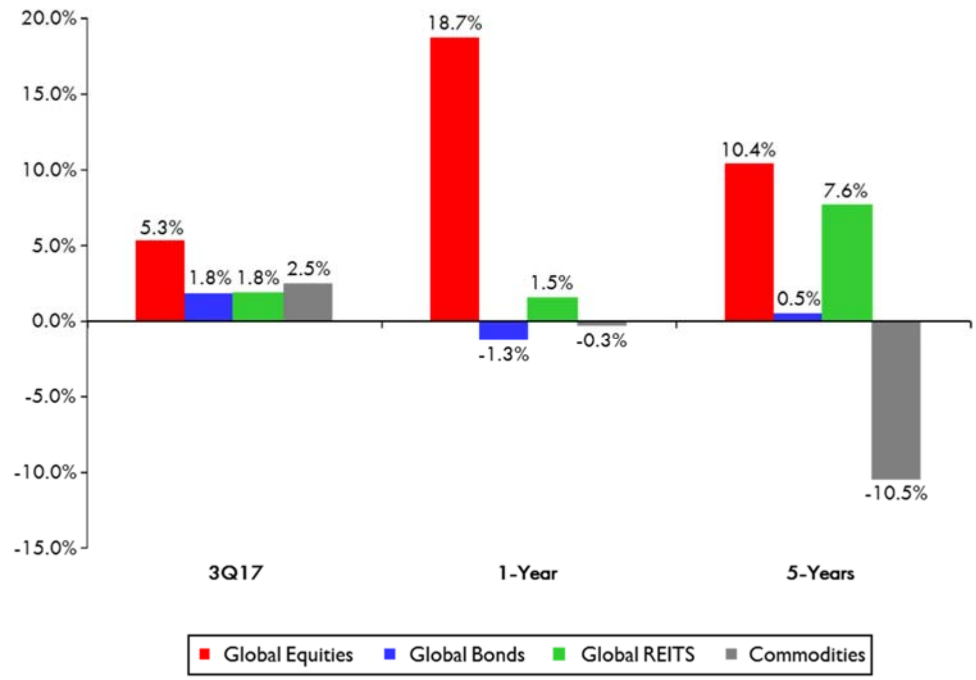
influence a wider territory, but are more vulnerable to capture, so the key is to balance strength through cohesion with the risks of expansion. Simple.

Chart 1 **Capital Market Performance**



The game spread across Asia, and took a special root in Japan, where it was called Go (碁), which is the name adopted by the West. Go was formally elevated in Japan when the shogun Tokugawa unified the country in 1602 and created a Cabinet-level Minister of Go. Four official schools of Go were authorized, with an annual tournament among them to determine the best player, who would then be awarded the title of meijin (名人). The truly exceptional player could achieve the rank of Sage, or Saint (kisei, 棋聖). Only three players in history have achieved that level.

The second Go Saint was named Jowa (1787-1847), and he headed the prestigious Honinbo school, which had been the home of the first Saint, Dosaku, more than one hundred years earlier. Given the exalted status of the meijin title, there was much political intrigue around its award. When Jowa was anointed meijin, the head of the Inoue school, a top player named Genan Inseki, was insulted that he had not won the honor, and he challenged Jowa to a match against his protégé, Intetsu Akaboshi, confident that Akaboshi, a nominally weaker player, would be able to win with Inseki's help.

For four grueling days they played. Inseki had devised a secret strategy, known as a taisha variation. No one had seen it before, and it caught Jowa by surprise and he soon fell behind. At that level of play, it is virtually impossible to overcome the slightest deficit, and Jowa seemed destined to defeat, loss of face, and even ritual suicide.

This match became the most famous game in the long history of Go. Its shocking conclusion was determined by just three moves, and to this day no one has been able to decipher Jowa's strategy or reasoning behind those moves. They were ethereal, inexplicable, and never duplicated.

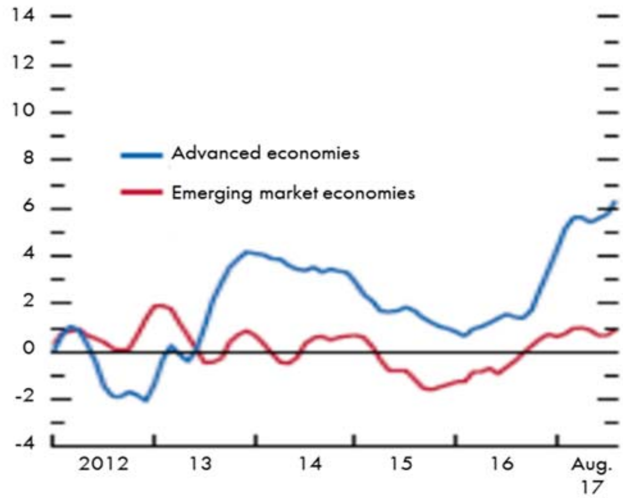
Go is a game of controlling territory by making connections across the board. Simple, but also enormously complex, like much of investing, and life.

Markets were strong in third quarter: stocks, bonds, real estate, commodities all advanced. Commodity price surges helped equities in producer countries. A 12% jump in crude oil sent the Norwegian krone up 5% and its equity market 19% higher. Hurricanes wiped out the Florida orange crop, sending orange juice soaring 14%, which was good news for Brazil's growers. The real rose about 5% and the Bovespa added more than 20%. Leading the pack last quarter was Ghana, where the 5% rise in cocoa prices sparked a 67% gain in that equity market. On the downside, Greek equities fell 12%, but are still 29% higher than a year ago. Not all commodity prices rose, and the market with the largest decline last quarter was lean hogs (not an oxymoron), which plunged 28%. Perhaps the insatiable demand for bacon has become satiated.

World capital markets have been strong because the global economy is gathering strength. A regional tour of selective indicators confirms the upward trend. In Asia, Chinese GDP has been stronger than expected, Korea's PMI[3] is at a two-year high, and Japan's PMI is at a four-year high. In Latin America, Mexican factory output is the most in more than a year, and Brazil's manufacturing output has risen six straight months. European GDP is stronger than anticipated, UK retail sales are up the most in two years, German manufacturing is rising, even Italy's industrial produc-

[3] Purchasing Managers index.

Chart 2 **Manufacturing PMI (Three-month moving average; deviations from 50)**



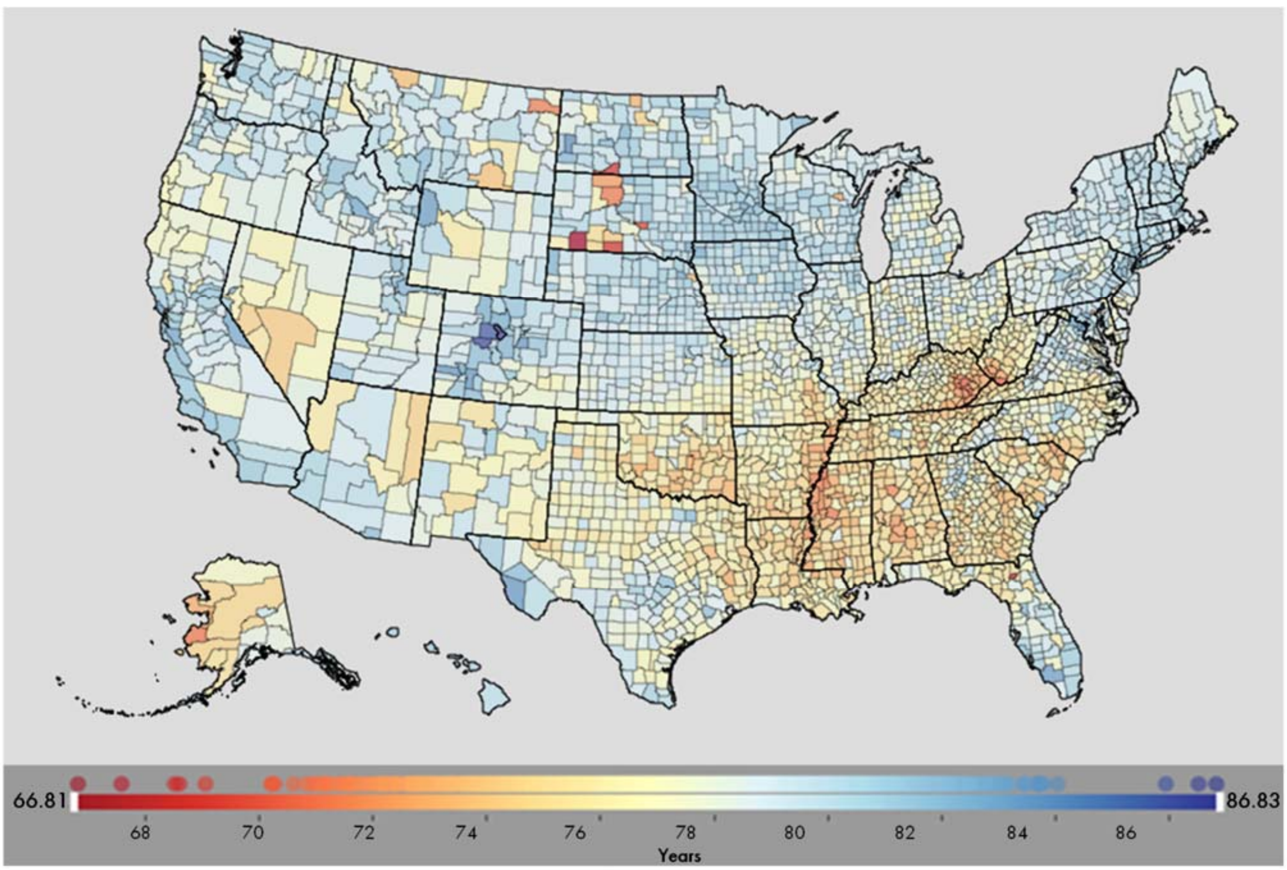
Source: IMF, World Economic Outlook, October 2017

Chart 3 **Consumer Confidence (Index, 2010 = 100)**

Source: IMF, World Economic Outlook, October 2017 tion has been up four straight months. And in the US, GDP has grown at a 3% pace for the past two quarters. The world economy is expected to rise 3.6% this year, up from 3.2% last year. Global trade, up 2.4% in volume terms last year, is forecast to grow 4% in 2017.

World economic growth can be seen in surging manufacturing, particularly among advanced economies (Chart 2 on page 3), where consumer confidence is the highest in a decade (Chart 3 on page 3). Nearly every country in the world will see positive GDP

Chart 4 **Life expectancy at Birth, Both Sexes, 2014**



Source: IHME

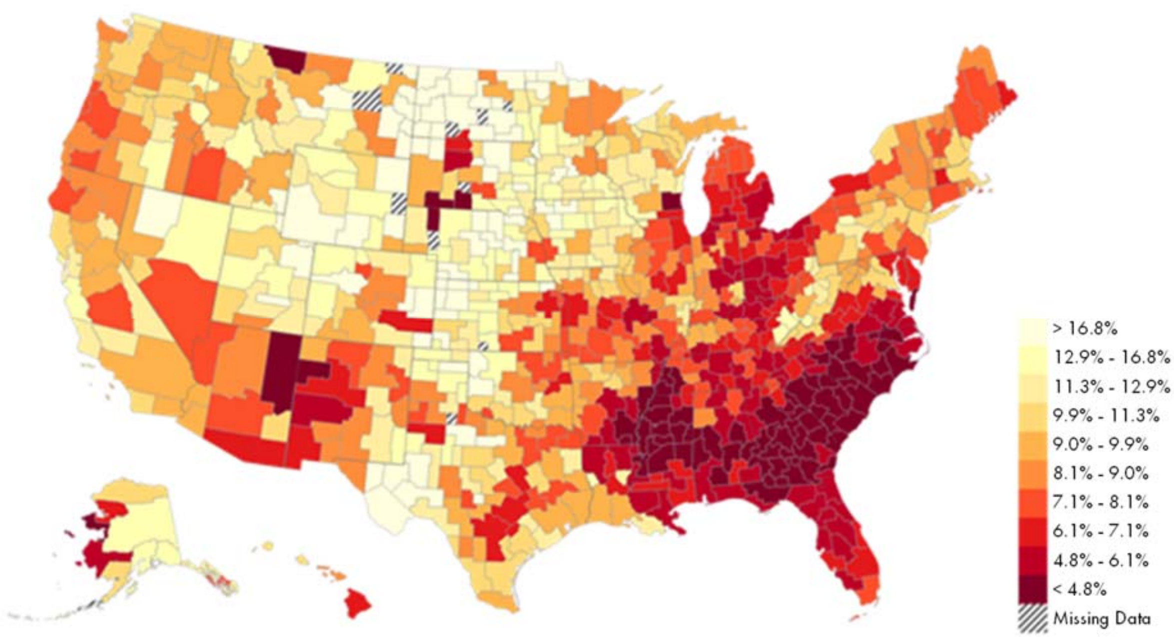
growth and moderating inflation this year and next, according to the IMF (with the stark and sad exception of Venezuela, where the combination of decades of disastrous socialist policies and two corrupt dictators saw the economy shrink 16% last year and another 12% this year. Inflation, at 254% in 2016, will be 653% this year, and 2,349% next year).[4]

Nearly all economic indicators are positive, which helps explain the strong performance across financial assets. But prosperity has bypassed many regions of the United States. Earlier this year we highlighted the rising mortality rates in many parts of the country, especially due to distress factors, such as overdose and suicide.[5] This, along with other factors, translates into a 20-year gap in life expectancy across geographies (Chart 4 on page 4).[6]

Not only are conditions dire in these regions, the prospects for material improvement are bleak. The chances of a child born in the bottom quintile of income reaching the top quintile are low. The best odds are in Salt Lake City and San Francisco, but even

Chart 5

The Geography of Upward Mobility in America
Children's Chances of Reaching Top 20% of Income Distribution Given Parents in Bottom 20%



Source: http://www.equality-of-opportunity.org/

4 IMF economists generate very precise estimates: 2,349.3% is their official estimate for Venezuela 2018 inflation.

5 https://angeles.srv.s3.amazonaws.com /content./1494344358./angeles-advisors-commentary-1qv217.pdf.

6 Source is the Institutes for Health Metrics and Evaluation, affiliated with the University of Washington.

there the probability of this upward mobility is just 11%. Children in the bottom income quintile in Boston, New York and Los Angeles have about a 10% chance of rising to the top quintile, and for a child in Houston it's about 8%, 6% in Chicago and a very bleak 4% in Atlanta (Chart 5 on page 5).[7] Note the similarity in graphic shading between these two maps.

This problem of inequality is enormously complex. Some of the explanation is surely cultural, but economic forces over the past few decades have contributed enormously and impacted communities in vastly different ways. Trade has brought huge benefits to consumers in the form of cheaper goods, and to the well-connected elite by opening global opportunities for commerce. But trade has also displaced many low-skilled manufacturing jobs that were often the primary economic opportunity for many communities. The populist promise to erect barriers by curtailing immigration and enacting tariffs appeals strongly to those whose jobs have been lost to immigrants and trade.

Anger directed against trade is largely misplaced, though, as only a fraction of job losses is linked to trade. Far more impactful has been technology. Robotics, automation, computers all favor the skilled and the educated, and thus threaten the unskilled and uneducated. But even skills and education are likely to be insufficient in holding on to many jobs. Daron Acemoglu (MIT) and Pascual Restrepo (Boston University) found that each new industrial robot replaced 5.6 workers, and every additional robot per 1,000 workers reduced employment by 0.34% and wages by 0.5%. They noted, "Interestingly, and perhaps surprisingly, we do not find positive and offsetting employment gains in any occupation or education groups."[8] In other words, the jobs lost were not replaced.

Technology usually advances incrementally, and it's only in hindsight that we can draw distinct eras. There are exceptions, when technology creates a truly new paradigm, such as the printing press or electricity, but mostly technological progress builds on itself over time. W. Brian Arthur of the Santa Fe Institute traces our Digital Age to the development of the integrated circuit in the 1960s and 1970s, which brought large-scale computing power to business and society.[9] A few decades later, fiber optics began to link computers in the 1990s, and the Internet emerged to allow the sharing of data and resources across the globe. This linking of computers empowered globalization, as tasks could be directed and coordinated remotely for the first time.

Our technology today is dominated by sensors of all kinds: gyroscopic, magnetic and radar sensors, temperature and pressure sensors, blood-chemistry sensors, hundreds of types of sensors linked together to detect the presence of objects or chemicals, enabling everything from Alexa and Siri and facial recognition to autonomous vehicles and monitoring our blood-sugar level.

These sensors generate massive amounts of data, "Big Data," that powerful computers translate into intelligent algorithms that control the technology. But this "intelligence" is not "understanding," as in human

[7] This project is led by Raj Chetty of Stanford, John Friedman of Brown and Nathaniel Hendren of Harvard.

[8] Daron Acemoglu and Pacual Restrepo, *Robots and Jobs: Evidence from US Labor Markets,* March 2017.

[9] The integrated circuit was patented by Jack Kilby of Texas Instruments in 1959, for which he shared the 2000 Nobel Prize for Physics. Robert Noyce, then at Fairchild Semiconductor, and later a co-founder of Intel, developed an integrated circuit independently that same year.

reasoning, rather something more akin to biological intelligence, as an organism "knows" through its electro-chemical sensors that food or a predator is near.

Even more important, notes Brian Arthur, is that this new intelligence is not designed by humans writing code. It is the result of computers applying advanced statistical methods to massive amounts of data to form associations, and connecting these associations to actions. This is "intelligence" that is independent of, and external to, humans. It is a form of intelligence that did not come from, or is controlled by, humans. It arises organically, albeit from inorganic electrons, and for the many problems it will solve and needs it will address, it will also disrupt our economies and rend our social fabric. How we control this emergent intelligence will be one of our biggest challenges.

Our universe is large, approximately 93 billion light years across. We can estimate the number of galaxies as between 300 and 500 billion, and each galaxy holds about 400 billion stars, so we estimate that the known universe contains between 120 and 300 sextillion (3×10^{23}) stars. Assuming each star weighs 10^{35} grams and each gram contains 10^{24} protons, we can estimate that there are between 10^{78} and 10^{82} number of atoms in the known universe. In English, that's one hundred thousand quadrillion vigintillion atoms. In simpler English, it's a lot of atoms.

Go is played on 19x19 board. John Tromp and Gunnar Farnebäck calculated that there are 2.08168199382... $\times 10^{170}$ legal positions in the game. To put that number in perspective, it is not only more than the total number of atoms in the universe, it is bigger than if every atom in the universe contained its own universe of atoms. The great chess champion, Emanuel Lasker, said, "If there are sentient beings on other planets, then they play Go."

In 1997, Deep Blue, a computer built by IBM, defeated Gary Kasparov, not only the reigning world chess champion at the time, but the highest ranked chess player in history. In 2011, IBM's Watson computer defeated Ken Jennings, who had won 74 consecutive matches on the TV show *Jeopardy!*. But Go is far more complex than chess or *Jeopardy!*, as *The Wall Street Journal* wrote in December 2015, "Why Go Still Fails the Computer."

The following month, January 2016, the prestigious journal *Nature*, published an article, "Mastering the Game of Go with Deep Neural Networks and Tree Search," by David Silver and a team at Deep Mind, a division of Google (now Alphabet). Two months later, in March 2016, their program, called AlphaGo, defeated Lee Sedol of South Korea, the top-ranked player in the world, in three straight games.

AlphaGo was loaded with 30 million games from an on-line game repository. It then played 30 million more games against itself, and used this set of data to defeat Lee Sedol. In May 2017, Deep Mind released 55 of the millions of games that AlphaGo played against itself, and experts have been studying them intently, and all are amazed. Humans build their positions methodically, balancing defense with attack. AlphaGo seems to employ multiple strategies simultaneously, and certain moves are completely idiosyncratic, without context to its strategy, as if deploying some alien logic that transcends human comprehension.

This month, the Deep Mind team published another article in the journal *Nature*,[10] introducing a new program, AlphaGo Zero, which learned to play Go simply by playing Go. That is, no previous data on games were loaded into this program, it "learned" by playing against itself. And it learned quickly. Where the original program played 30 million games, this new one played just 3.9 million. The original AlphaGo was powered by 48 Tensor Processing Units (TPUs),[11] developed specifically by and for Google. AlphaGo Zero used just 4 TPUs, one-tenth of the computing power of the first program, and ran on a single system, not on distributed computing, meaning anyone with a few Nvidia chips can run it.

AlphaGo Zero played AlphaGo in one hundred games. It won all of them. AlphaGo Zero had two distinct advantages over the original program. It conducts self-play utilizing Monte Carlo Tree Search ("MCTS"). Each play can lead to many possible outcomes, much like going up a tree trunk can lead to many branches. MCTS expands the search using random sampling, notes which moves seem to lead to better results, focusing on the more promising out-

10 "Mastering the game of Go without human knowledge," *Nature* 550, 354–359, 19 October 2017.

11 1 TPU = 180 teraops; that's a lot of computing power.

comes in its subsequent random searches. So the process is not about testing more data, but finding better data, testing that, leading to improved results.

The other advantage AlphaGo Zero had was no knowledge of human play, so any human biases that have developed over thousands of years, such as the accepted strategic progression of building positions first in the corners, then the sides and finally moving to the center of the board, were unknown to the program. This was a crucial advantage. David Silver of Deep Mind noted, "It's more powerful than previous approaches because by not using human data, or human experience in any fashion, ***we've removed the constraints of human knowledge*** and it is able to ***create knowledge itself***" (my emphasis).

Consider the implications of this statement: human knowledge is no longer the force behind technological progress but an impediment. Every function of our economy and society will rely on an intelligence created by programs without our input or guidance in a language that we cannot understand. The full consequences of this are unknown, but are certain to be profound.

In the past, access to wealth was determined by inheritance (for much of history only the nobility was wealthy). In the modern era, the benefits of technology were available to anyone with a job or education. But in the past few decades, technological progress, and the wealth it connects to, has bypassed large portions of the population. How do we remedy this and share the opportunities of technology to those who do not have the right education, or the right jobs, or live in the right places? How do we balance our right to privacy with access to the benefits of technology, and, more profoundly, how do we impart meaning in lives that have been disrupted by technology and have neither jobs nor education or hope for their future?

These are some of our deepest challenges, and as we consider them, it's worthwhile remembering Albert Einstein's admonition: "It is not enough that you should understand about applied science in order that your work may increase men's blessings. Concern for the man himself and his fate must always form the chief interest of all technical endeavors.... Never forget this in the midst of your diagrams and equations."

Go is a simple game about making connections across an enormously complex set of paths. This is precisely our task as we navigate the intricate interaction among politics, economics and cultures that are being impacted, influenced and interrupted by emergent technologies.

Jowa (https://senseis.xmp.net/?Jowa)

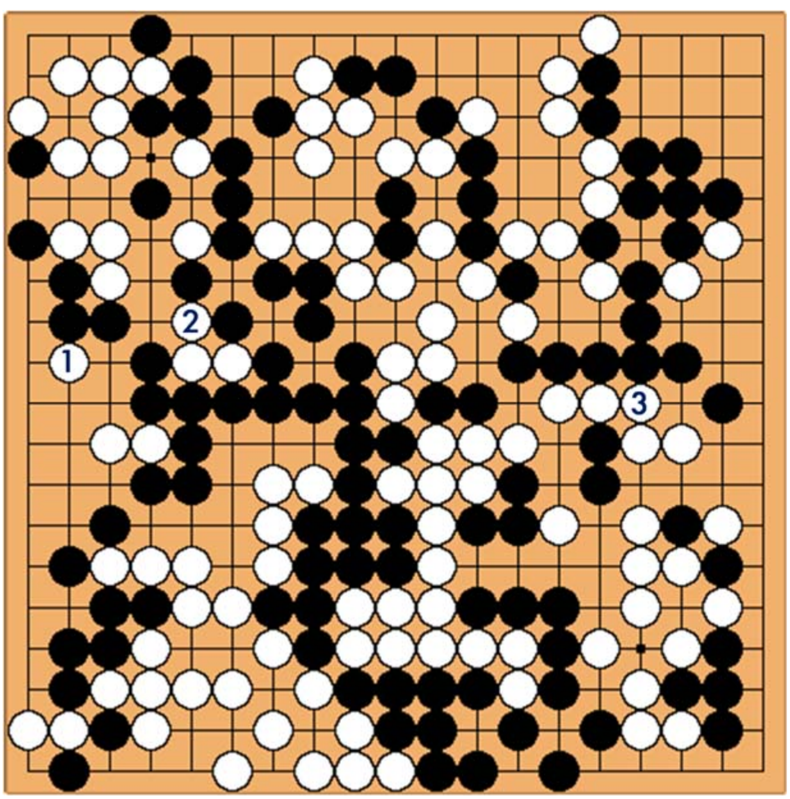
As for Jowa, he faced certain defeat against the younger Akaboshi. But at the end of the four-day marathon match, he played three successive moves that were incomprehensible; they seemed to have no purpose, neither defending territory nor threatening Akaboshi's position. Yet within minutes, it became clear that these three moves had given Jowa an unassailable advantage, turning certain defeat into a stunning victory (see Board below). That game became the most famous in history, given the macabre epithet, "the blood-vomiting game," because just as Akaboshi conceded the match, he fell ill, and died.

Scholars have studied these three moves for nearly two hundred years, and cannot explain how Jowa thought of them. Jowa could only offer that ghosts entered his mind and showed him these moves, and that has been the accepted explanation ever since. Similarly, the rationale of AlphaGo Zero seems incomprehensible to us, as if it has created its own language completely alien to humans, written by, well, ghosts.

Of course, we all know that ghosts aren't real.

Or are they?

Ending Position; Three Ghost Moves Marked



(https://senseis.xmp.net/?BloodVomitingGame)

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October 2017

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