Summary

Algorithms are the step-by-step instructions used in computing for achieving desired results, much like recipes in cooking. In both cases the recipe design- er has a certain controlled environment in mind for realizing the recipe, and foresees how the desired outcome will be achieved. The algorithms I discuss in this book are special. Unlike most algorithms, they can be run in environ- ments unknown to the designer, and they learn by interacting with the envir- onment how to act effectively in it. After sufficient interaction they will have expertise not provided by the designer, but extracted from the environment. I call these algorithms ecorithms. The model of learning they follow, known as the probably approximately correct model, provides a quantitative frame- work in which designers can evaluate the expertise achieved and the cost of achieving it.

算法是用于计算为实现预期的结果，就像在烹饪食谱的分步指导。在两种情况下配方设计-呃某些受控的环境，实现食谱，并预见到将如何实现所期望的结果。我在这本书中讨论的算法都是特别的。与大多数算法不同的是他们可以在运行环境未知设计师，和他们学习如何采取有效行动，在它与环境环境交互。经过充分的互动就有不提供的设计器，但从环境中提取出来的专门知识。我打电话给这些算法 ecorithms。学习他们遵循，称为可能大体正确的模型，该模型提供定量的框架工作的设计师可以评估取得的专门知识和实现它的成本。

These ecorithms are not merely a feature of computers. I argue in this book that such learning mechanisms impose and determine the character of life on Earth. The course of evolution is shaped entirely by organisms inter- acting with and adapting to their environments. This biological inheritance, as well as further learning from the environment after conception and birth, have a determining influence on the course of an individual’s life. The focus here will be the unified study of the mechanisms of evolution, learning, and intelligence using the methods of computer science.

这些 ecorithms 并不只是计算机的一项功能。我认为在这本书中，这种学习机制施加，确定地球上的生命的字符。进化过程中的是完全由有机体与除代理和适应其环境塑造的。此生物的继承，以及进一步从环境中学习怀孕后，有决定性影响的个人的生命历程。这里的重点将是统一的研究机制的演变、 学习和使用计算机科学的方法的情报。

The book has the following simple structure. Chapters 1, 2, and 4 set the scene for the natural phenomena to which the quantitative computational approach is to be applied. Chapter 3 is an introduction to computer science, particularly the quantitative study of algorithms and their complexity, and describes the background for the methodology used. Chapters 5, 6, and 7 contain the resulting theory for learning, evolution, and intelligence, respectively. The final chapters make some informal and more speculative suggestions with regard to some consequences for humans and machines.

这本书有以下的简单结构。1、 2 和 4 的章节设置现场为定量的计算方法将被应用到的自然现象。3 章是导论计算机科学，特别是算法的定量研究和它们的复杂性，并介绍了使用的方法的背景。5、 6 和 7 的章节分别包含为学习、 进化和情报，由此产生的理论。最后几章对人和机器使谈一些后果的一些非正式和更多的投机的建议。

Chapter One Ecorithms

In 1947 John von Neumann, the famously gifted mathematician, was key- note speaker at the first annual meeting of the Association for Computing Machinery. In his address he said that future computers would get along with just a dozen instruction types, a number known to be adequate for ex- pressing all of mathematics. He went on to say that one need not be sur- prised at this small number, since 1,000 words were known to be adequate for most situations in real life, and mathematics was only a small part of life, and a very simple part at that. The audience reacted with hilarity. This pro- voked von Neumann to respond: “If people do not believe that mathematics is simple, it is only because they do not realize how complicated life is.”1

1947 年约翰 · 冯 · 诺依曼，著名数学家，是主讲人的计算机械协会第一次年度会议。在讲话中他说: 未来的计算机会相处十几只是指令类型，数已知的对前压所有的数学都是足够的。他接着说，一个不需要 sur-撬在这个小的数字，因为已知 1000 字要足够应对大多数情况下，现实生活中，和数学是只有一小部分的生活和一个非常简单的零件，在那。观众反应与欢乐。这 pro voked · 冯 · 诺依曼作出回应:"如果人们不相信，数学是简单，它是只是因为他们不知道如何复杂的生活是"。1

Though counterintuitive, von Neumann’s quip contains an obvious truth. Einstein’s theory of general relativity is simple in the sense that one can write the essential content on one line as a single equation. Understanding its meaning, derivation, and consequences requires more extensive study and effort. However, this formal simplicity is striking and powerful. The power comes from the implied generality, that knowledge of one equation alone will allow one to make accurate predictions about a host of situations not even conceived when the equation was first written down.

虽然有悖常理，冯 · 诺依曼的妙语包含一个显而易见的事实。爱因斯坦的广义相对论理论是简单意义上，一个能在同一行中作为一个单一的方程写的基本内容。了解其含义、 派生和后果需要更广泛的研究和努力。然而，这种正式的简单性是引人注目和强大。力量来自于隐含的一般性原则下，单独的一个方程的知识会允许自己作出准确的预测很多的情况下甚至没有设想时，方程第一次写下来。

Most aspects of life are not so simple. If you want to succeed in a job inter- view, or in making an investment, or in choosing a life partner, you can be quite sure that there is no equation that will guarantee you success. In these endeavors it will not be possible to limit the pieces of knowledge that might be relevant to any one definable source. And even if you had all the relevant knowledge, there may be no surefire way of combining it to yield the best decision.

生活的大多数方面并不那么简单。如果你想要成功的工作除-在视图中，或在作出投资，或在选择人生伴侣，你可以肯定是不能保证你成功的方程。在这些工作中它将不可能限制可能与任何一个可定义源有关的知识的碎片。而且即使你有所有的相关的知识，可能没有万全之策相结合产生的最好的决定。

“This book is predicated on taking this distinction seriously. Those aspects of knowledge for which there is a good predictive theory, typically a mathematical or scientific one, will be called theoryful. The rest will be called theoryless. I use the term theory here in the same sense as it is used in science, to denote a “good, effective, and useful theory” rather than the negative sense of “only a theory.” Predicting the orbit of a planet based on Newton’s laws is theoryful, since the predictor uses an explicit model that can accurately predict everything about orbits. A card player is equally theoryful in predicting an opponent’s hand, if this is done using a principled calculation of probabilities, as is a chemist who uses the principles of chemistry to predict the outcome of mixing two chemicals.

"这本书被取决于认真对待这种区分。这些方面的知识是一个好的预测理论，通常数学或科学的人，将被称为 theoryful。其余将被称为 theoryless。我使用期限理论在这里在同一意义上，它用在科学中，来表示"好的、 有效的和有用的理论"而不是负面意义的"只是理论"。预测基于牛顿定律的轨道是行星的 theoryful，因为预测使用显式的模型，可以准确地预测轨道的一切。打牌的人是同样 theoryful 在预测对手的手里，如果这样做是使用原则计算的概率，一名化学家使用化学原理来预测混合两种化学物质的结果。

In contrast, the vast majority of human behaviors look theoryless. Nevertheless, these behaviors are often highly effective. These abundant theoryless but effective behaviors still lack a scientific account, and it is these that this book addresses.

与此相反的是，绝大多数的人类行为看 theoryless。然而，这些行为往往是非常有效的。这些丰富的 theoryless 但有效行为仍然缺乏科学的解释，和它是这本书涉及的这些。

“The notions of the theoryful and the theoryless as used here are relative, relative to the knowledge of the decision maker in question. While gravity and mechanics may be theoryful to a physicist, they will not be to a fish or a bird, which still have to cope with the physical world, but do so, we presume, without following a theory. Worms can burrow through the ground without apparently any understanding of the physical laws to which they are subject. Most humans manage their finances adequately in an economic world they don’t fully understand. They can often muddle through even at times when experts stumble. Humans can also competently navigate social situations that are quite complex, without being able to articulate how.

"Theoryful 和 theoryless 用在这里的概念是相对的相对于决策者问题的知识。虽然重力和力学可能 theoryful 一位物理学家，他们不会对一条鱼或者一只鸟，当中仍有应付物理的世界，但这样做，我们相信，没有按照理论。蠕虫可以挖洞通过地面没有显然任何他们受到的物理法则的理解。大多数人类管理他们充分参与经济的世界，他们不完全理解的财务状况。他们往往能蒙混过关，有时甚至当专家跌倒。人类也胜任可以导航是相当复杂，不能表达的社会情况如何。

“In each of these examples the entity manages to cope somehow, without having the tenets of a theory or a scientific law to follow. Almost any biological or human behavior may be viewed as some such coping. Many instances of effective coping have aspects both of the mundane and also of the grand and mysterious. In each case the behavior is highly effective, yet if we try to spell out exactly how the behavior operates, or why it is successful, we are often stumped. How can such behavior be effective in a world that is too complex to offer a clear scientific theory to be followed as a guide? Even more puzzling, how can a capability for such effective coping be acquired in the first place?”

"在每个示例实体管理应付不知怎的没有一个理论或科学的规律，遵循的原则。几乎任何生物或人类的行为可能被视为一些这种应对。很多情况下的有效应对有世俗的和宏伟和神秘的方面。在每个案件的行为是高度有效，但如果我们尝试拼出确切的行为是如何运作的或者为什么它是成功的我们是经常难住了。如何这样的行为能有效在是太复杂，无法提供明确的科学理论作为指导应遵循的世界呢?更令人费解的怎么可以这样有效的应对能力获得放在第一位?"

Science books generally restrict their subject matter to the theoryful. However, I am impressed with how effectively life forms “cope” with the theoryless in this complex world. Surely these many forms of coping have some commonality. Perhaps behind them all is a single basic phenomenon that is itself subject to scientific laws.

科学书籍一般限制其主题 theoryful。然而，我是如何有效地生命形式"应付"与 theoryless 在这个复杂的世界的印象。当然这些许多形式的应对有一些共性。也许在他们后面都是一个单一的基本现象，本身就是科学的法律。

This book is based on two central tenets. The first is that the coping mech- anisms with which life abounds are all the result of learning from the envir- onment. The second is that this learning is done by concrete mechanisms that can be understood by the methods of computer science.

这本书基于两个核心原则。第一是应对机制生活丰富都是从环境环境学习的结果。第二是这种学习通过具体的机制，可以理解的计算机科学的方法。

On the surface, any connection between coping and computation may seem jarring. Computers have traditionally been most effective when they follow a predictive science, such as the physics of fluid flow. However, com- puters also have their softer side. Contrary to common perception, computer science has always been more about humans than about machines. The many things that computers can do, such as search the Web, correct our spelling, solve mathematical equations, play chess, or translate from one language to another, all emulate capabilities that humans possess and have some interest in exercising. Depending on the task, the performance of present-day computers will be better or worse than humans. But in regard- ing computers merely as our slaves for getting things done, we may be miss- ing the point. The overlap between what computers and humans do every day is already vast and diverse. Even without any extrapolation into the fu- ture, we have to ask what computers already teach us about ourselves.

表面上看，任何应对和计算之间的连接可能显得刺耳。当他们按照预测的科学，如流体流动的物理计算机历来最有效。然而，com 电脑也有自己温柔的一面。与普遍看法相反计算机科学一直是关于有关机器比人类更多。很多事情，计算机可以做，如搜索 Web，纠正我们的拼写、 解决数学方程、 下棋，或从一种语言翻译到另一个，所有模拟功能人类拥有和行使的一些兴趣。根据任务，当今的计算机的性能将比人类好或差。但方面 ing 在计算机中只是作为我们做事的奴隶，我们可能想着点。每天做什么计算机和人类之间的重叠部分已经是庞大和多元化。即使没有任何外推到福真的，我们要问计算机已经教给我们什么......

The variety of applications of computation to domains of human interest is a totally unexpected discovery of the last century. There is no trace of any- one a hundred years ago having anticipated it. It is a truly awesome phe- nomenon. Each of us can identify our own different way of being impacted by the range of applications that computers now offer. A few years ago I was interested in the capabilities of a certain model of the brain. In a short, hermit-like span of a few weeks I ran a simulation of this model on my laptop and wrote up a paper based on the calculations performed by my laptop. I used a word processor on the same laptop to write and edit the art- icle. I then emailed it off to a journal again from that laptop. This may sound unremarkable to the present-day reader, but a few generations ago, who would have thought that one device could perform such a variety of tasks? Indeed, while for most ideas some long and complex history can be traced, the modern notion of computation emerged remarkably suddenly, and in a most complete form, in a single paper published by Alan Turing in 1936.2

各种应用程序域对人类感兴趣的是计算的上个世纪完全意外的发现。一百多年前有预期它还有没有跟踪任何人。它是真正可怕现象。我们每个人都可以确定我们自己不同的方式受到计算机现在提供的应用范围。几年前我很感兴趣，大脑某些模型的功能。在短短的几个星期隐士般的短我跑这个模型模拟在我的笔记本上，写了一份文件，基于我电脑上执行的计算。我用于文字处理器相同的笔记本电脑上编写和编辑艺术单粒子轨迹。我然后通过电子邮件发送它掉到某一日志再次从那台手提电脑。这可能听起来不起眼到现代的读者，但几代之前，都没有想到，一个设备可以执行各种各样的任务吗?事实上，虽然大多数的想法可以追溯一些漫长而复杂的历史，现代概念的计算出现了非常突然，和以最完整的形式，在一张纸在 1936.2 发表的 Alan Turing

Science prior to that time made no mention of abstract machines. Turing’s theory did. He defined the mathematical notion of computation that our all- pervasive information technology now follows. But in offering his work, he made it clear that his goal went beyond understanding only machines: “We may compare a man in the process of computing a real number to a machine which is only capable of a finite number of conditions.” With these words he was declaring that he was aiming to formalize the process of computation where a human mechanically follows some rules. He was seeking to capture the limits of what could be regarded as mechanical intellectual work, where no appeal to other capabilities such as intuition or creativity was being made.

之前这段时间的科学抽象机器没有提到。图灵的理论做了。他定义我们所有普遍存在的信息技术现在跟随的计算的数学概念。但在提供他的工作，他清楚，他的目标超出了理解只有机器:"我们可能比较过程中计算一个实数的一台机器，是唯一能够条件有限数目的人"。说完这些话他宣布，他的目标正式确定在哪里人机械地遵循一些规则的计算过程。他想要捕捉的什么可以被视为机械的智力劳动，有人被其他功能，如直觉或创造力没有呼吁限制。

Turing succeeded so well that the word computation is now used in ex- actly the sense in which he defined it. We forget that a “computer” in the 1930s referred to a human being who made a living doing routine calcula- tions. Speculations that philosophers or psychologists entertained in earlier times as to the nature of mechanical mental capabilities equally dim in the memory. Turing had discovered a precise and fundamental law that both liv- ing and inert things must obey, but which only humans had been observed to exhibit up to that time. His notion is now being realized in billions of pieces of technology that have transformed our lives. But if we are blinded by this technological success, we may miss the more important point that Turing’s concept may enable us to understand human activity itself.

图灵成功所以那词计算是现在用在前-明目张胆地在其中他定义它的含义。我们忘了在 20 世纪 30 年代的"计算机"指作做例行规律性生活的人。哲学家或心理学家受理在更加早期的时期的机械的心理功能性质的猜想同样暗淡在内存中。图灵发现了精确和基本的法律，丽芙 ing 和惰性物质必须服从，但其中唯一的人类已经被观察到陈列到那个时候。他的想法，现在在数以十亿计的技术，改变了我们的生活。但如果我们蒙蔽了此技术的成功，我们可能会错过，图灵的概念可能会使我们能够理解人类活动本身更重要的一点。

This may seem paradoxical. Humans clearly existed before Turing, but Turing’s notion of computation was not noticed before his time. So how can his theory be so fundamental to humans if little trace of it had even been suspected before?

这看起来似乎自相矛盾。人类显然存在之前图灵机，但计算图灵机的概念不注意到之前，他的时间。所以他的理论如果怎能如此基本的人类小的微量甚至曾怀疑之前吗?

My answer to this is that even in the pre-Turing era, in fact since the be- ginning of life, the dominating force on Earth within all its life forms was computation. But the computations were of a very special kind. These com- putations were weak in almost every respect when compared with the capab- ilities of our laptops. They were exceedingly good, however, at one enter- prise: adaptation. These are the computations that I call ecorithms—al- gorithms that derive their power by learning from whatever environment they inhabit, so as to be able to behave effectively in it. To understand these we need to understand computations in the Turing sense. But we also need to refine his definitions to capture the more particular phenomena of learn- ing, adaptation, and evolution.

我的答案是，即使在前图灵时代，事实上因为是: 轧花的生活，在地球上一切生命形式内的主导力量是计算。但计算是一种非常特殊。这些楼板很弱在几乎每一个方面与我们的笔记本电脑社会荫庇相比。他们都非常的好，但是，在一个输入企业: 适应。这些都是我叫 ecorithms 的计算 — — al gorithms 派生通过学习无论环境如何从他们居住，以便能够在它有效地表现他们的力量。要了解这些我们需要了解在图灵意义上的计算。但我们还需要改进他的定义，以捕获的学习、 适应和进化的更特殊的现象。

Understanding learning has been one of my personal research goals for several decades. The natural phenomenon of young children learning is ex- traordinary. A spectacular facet of this learning is that, beyond remembering individual experiences, children will also generalize from those experiences, and very quickly. After seeing a few examples of apples or chairs, they know how to categorize new examples. Different children see different examples, yet their notions become similar. When asked to categorize examples they have not seen before, their rate of agreement will be remarkably high, at least within any one culture. Young children can sort apples from balls even when both are round and red.

了解学习一直是我个人的研究目标了几十年。幼儿学习的自然现象是怪。这种学习的壮观一面是超越记忆的个人经验，孩子将也概括从这些经验，并很快。在看到苹果或椅子的几个例子，他们知道如何进行分类的新例子。不同的孩子看到不同的例子，但他们的想法变得相似。当要求分类他们以前没见过的例子，他们的协议率会非常高，至少内任何一种文化。年幼的孩子可以排序从球甚至苹果都是圆的红色的时候。

This ability to generalize looks miraculous. Of course, it cannot really be a miracle. It is a highly reproducible natural phenomenon. Ripe apples fall from the tree to the ground predictably enough that one can base a universal law of gravitation on this phenomenon. Children generalizing successfully from their specific experiences manifest a similarly predictable phenomenon, which therefore also begs for a scientific explanation. I seek to explain this in terms of concrete computational processes.

这种能力来概括看起来很神奇。当然，它不能真的是个奇迹。它是一个高度重复性的自然现象。熟透了的苹果落从树上到地面不出所料，一个人可以依据对这一现象万有引力定律。孩子们从他们具体的经验成功地推广表现同样可预测的现象，因此也乞求一个科学的解释。我试图解释这具体的计算过程。

The phenomenon of generalization has been widely discussed by philo- sophers for millennia. It has been called the problem of induction. I have found that as a scientist I have some advantages over philosophers: It is suf- ficient to aim to capture the fundamental part of a specific reproducible phe- nomenon. I need not explain all of the many senses in which the words in- duction or generalization have been used. Scientific discovery—for example, Johannes Kepler discovering his laws of planetary orbits—may have some commonality with the phenomenon of generalization exhibited by children learning words, but it may be a secondary and harder to reproduce by- product of a more basic and fundamental capability. Turing did not attempt to capture all the connotations that the word computing may have had in his day. He sought only to uncover a phenomenon associated with that word that had fundamental reality independent of any word usage.

千百年来，斐洛 sophers 被广泛讨论的泛化现象。它被称为归纳问题。我发现作为一名科学家，我有一些哲学家的优势: 它是主要旨在捕获特定重现现象的基本部分。我不需要解释所有在其中的很多感官尚未使用词在生产或泛化。科学发现 — — 例如，约翰内斯 · 开普勒发现他的行星轨道定律 — — 可能有一些共性与泛化现象所表现的儿童学习单词，但它可能产生的次要的和难以重现的更基本和基本能力的产品。图灵亦未能捕获 word 计算可能已经在他的一天的所有内涵。他只是试图揭开与有独立于任何词的用法的基本现实这个词相关联的现象。

What kind of explanation of induction do we need? Does it need to be mathematical? There is no better answer to this than what is implicit in the work of Turing himself. I have already referred to his successful mathematic- al formulation of computation. But he is also famous for the notion that is now known as the Turing Test, which he offered as a test for recognizing whether a machine can be considered to think. A simplified definition is as follows. A machine passes the Turing Test if a person, conversing with it via remote electronic interactions, cannot distinguish it from a person. The Tur- ing Test is an important notion, and researchers in artificial intelligence have not succeeded in either building machines that can pass the test or in showing it to be irrelevant. However, it is an informal notion. Unlike Tur- ing’s mathematical definition of computation, it does not tell us how exactly to proceed in order to emulate thinking. As a result, it has not led to progress in artificial intelligence remotely comparable to the success of general computation.

我们需要什么样的感应解释?它不必是数学?还有没有更好的答案，这比什么是隐式的图灵自己工作。我已经提到他成功的数学基地制定的计算。但他也是著名的现在被称为图灵测试，他主动提出作为识别是否可以被视为一台机器，想测试的概念。一个简化的定义是，如下所示。如果一个人，与它交谈，通过远程电子相互作用，不能区分它从一个人一台机器通过图灵测试。Tur ing 测试是一个重要的概念，并在人工智能领域中的研究者不成功可以通过考试或建筑机器或显示它是不相关。然而，它是一个非正式的概念。与 Tur ing 计算的数学定义，不同的是它并没有告诉我们到底是如何来行事，以模仿思维。结果，它并未在人工智能远程媲美成功的一般计算方面取得进展。

Hence the right goal must be to find a mathematical definition of learning of a nature similar to Turing’s notion of computation, rather than an informal notion like the Turing Test. After all, where would we be if Turing had given for computation only an informal definition? Let us think about that. What would have been an informal notion of the “mechanically com- putable” that would have sounded plausible in Turing’s time? How about this: “A task is mechanically computable if and only if it can be computed by a person of average intelligence while at the same time doing a mundane but exacting task, such as eating spaghetti.” Few could have disputed the reason- ableness of such a definition. But I doubt such a definition in 1936 could have spawned the twenty-first century we see around us.

因此正确的目标一定要找到学习性质的数学定义类似于计算，图灵机的概念，而不是一个非正式的概念，像图灵测试。毕竟，在那里我们会如果图灵曾给出了计算只是一个非正式的定义呢?让我们想想的。什么会被一个非正式的"机械 com-putable"的概念，会有听起来似乎可信在图灵的时间吗?这个怎么样:"的任务是机械可计算当且仅当它可以计算一个人的平均智力同时做一个平凡但也很严格的任务，如吃意大利面条。很少有人能争执原因手术的这一定义。但我怀疑这种定义在 1936 年可能繁衍了第二十一世纪我们看到在我们周围。

At the heart of my thesis here is a mathematical definition of learning. It is called the PAC or the probably approximately correct model of learning, and its main features are the following:3 The learning process is carried out by a concrete computation that takes a limited number of steps. Organisms can- not spend so long computing that they have no time for anything else or die before they finish. Also, the computation requires only a similarly limited number of interactions with the world during learning. Learning should en- able organisms to categorize new information with at most a small error rate. Also, the definition has to acknowledge that induction is not logically fail-safe: If the world suddenly changes, then one should not expect or re- quire good generalization into the future.

在我的心在这里是论文的学习数学定义。它被称为 PAC 或学习，可能大约正确模型，其主要特点是学习的过程由具体的计算采用有限的数量的步骤如下: 3。生物体不能花这么长时间计算，他们都没有时间做别的事情死之前他们完成。此外，计算在学习过程中需要只有同样有限的数目与世界的互动。学习应该 en-能生物进行分类的新信息与最小错误率。定义而且，不得不承认感应并不是逻辑上万全之策: 如果世界突然发生变化，则不应指望或成未来再需要良好的泛化。

The biology of living organisms can be described in terms of complex cir- cuits or networks that act within and between cells. Our biology is based on proteins and the interactions among them. Our DNA contains more than 20,000 genes that describe various proteins. Additionally, the DNA encodes descriptions of the regulation mechanism, a specification of how much new protein of each kind is to be produced, or expressed. This overall regulation mechanism is absolutely fundamental to our biology, and is called the pro- tein expression network. It is of enormous complexity. Even though many of its details remain to be discovered, we can ask: How have these well-func- tioning, highly intricate networks with so many interlocking parts come in- to being? I believe that all these circuits are the result of some learning process instigated by the interactions between a biological entity and its environment.

生物体的生物可以描述复杂的 cir cuits 或行动内及细胞间的网络。我们的生物学基于蛋白质和它们之间的交互。我们的 DNA 包含超过 20000 个描述各种各样的蛋白质的基因。此外，DNA 编码的调控机制的描述，多少新的蛋白质，每种规格是被生产，或者表示。这个整体的规管机制是我们生物的根本原则，被称为 pro 蛋白表达网络。它是极其复杂。尽管很多它的细节问题仍被发现，我们可以问: 怎么有这么多的联锁部分这些调节功能好，高度复杂网络来到在-被?我相信所有这些电路是由一个生物实体与它的环境之间的相互作用煽动一些学习过程的结果。

Life’s interactions can be viewed in terms of either a single organism’s life- time or the longer spans during which genes and species evolve. In either case the information gained by the entity from the interaction is processed in some mechanical way by what I call an ecorithm. The primary purpose of the ecorithm is to change the circuits so that they will behave better in the envir- onment in the future and produce a better outcome for the owner.

生活中的相互作用可以看作一个单一的有机体生命时间或其间基因和物种进化的更长的时间跨度。在任一情况下一些机械的方式称之为 ecorithm 处理由实体的交互作用中获得的信息。Ecorithm 的主要目的是要改变电路，将在未来环境环境中更好地表现为所有者产生更好的结果。