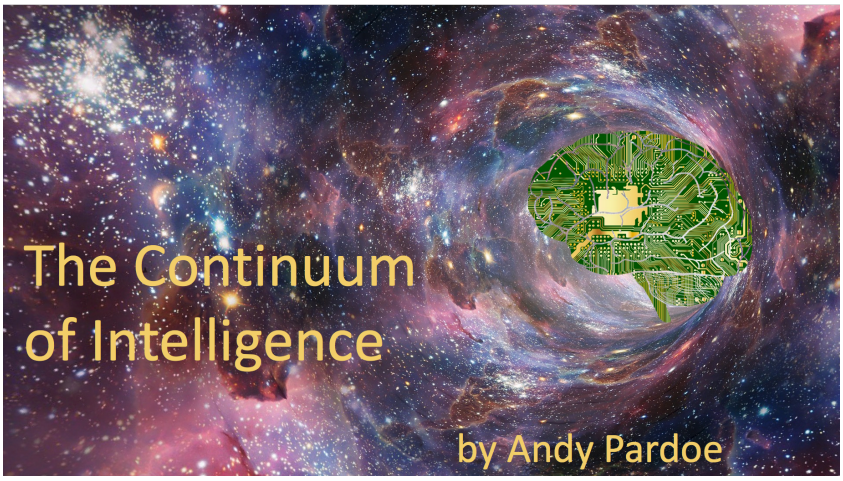

The Continuum of Intelligence

What if the only purpose of the universe and the evolution of life was for the advancement of intelligence. Darwin was wrong, its not “survival of the fittest”, its “survival of the smartest”. The pursuit of advanced intelligence is our true purpose and will lead to answers to many of the biggest questions that currently challenge us. The Continuum of Intelligence is a roadmap for the journey towards advanced intelligence.

Abstract

The purpose of this article is to help provide a mechanism or index to measure the progress of the field of artificial intelligence towards artificial general intelligence, super intelligence and beyond. There is much uncertainty as to when these milestones will be achieved, but without a measure of progress towards them, it becomes even more difficult to determine when they might occur. This article will not only provide an index of the continuum of intelligence in which to measure our progress to achieving advanced AI, but will also give a considered view on some related topics, such as consciousness, dreaming and personality. Much has been written on these topics from physicists, mathematicians, neuroscientists, philosophers and phycologists, but here I provide a computer scientist’s perspective.

This article provides a preview of my book, by the same title, to be released in 2018.

Introduction

At almost every meeting and conference on AI most of us will at some stage be involved in a discussion on the definition of Artificial Intelligence. The reason for this is quite simple. As an industry we don't have a universally accepted definition of AI [8]. Yes we have the Turing Test, but this only provides one milestone on the journey towards advanced artificial intelligence. It does not define what intelligence is, or even specify the elements of intelligence. When two dozen prominent theorists were recently asked to define intelligence, they gave two dozen, somewhat different, definitions [2,7]. The problem is much wider than just the field of Artificial Intelligence. The study of the brain and consciousness, with thousands of research papers from the field of psychology and neuroscience, still does not have a single universally accepted definition of consciousness.
As we continue to develop more and more intelligent systems, not having a single universally accepted definition of intelligence will become more problematic for a number of different reasons, not least when we consider the legal and ethics aspects of the systems we build.

We have been asking the wrong question. We should not be trying to find a single definition of artificial intelligence or even just intelligence, but with the understanding that there is a range of

intelligent capabilities, we should be looking to define the range of intelligent behaviours. There already is much work in the space to help define theoretical frameworks for intelligence. From the MIT Centre for Brains, Minds and Machines “Understanding intelligence and the brain requires theories at different levels, ranging from the biophysics of single neurons, to algorithms and circuits, to overall computations and behaviour, and to a theory of learning. In the past few decades, advances have been made in multiple areas from multiple perspectives.” [11]

This leads us to potentially complicated frameworks, that leverage the different fields of research to describe them. This becomes somewhat of a impediment to its common use as they are not singularly aligned to the approaches and language used by those using and developing machine intelligence. This article rectifies this, by constructing a detailed but simple definition of the different levels of intelligence on the journey to super intelligence and the singularity. This index of intelligence, or continuum, will have the greatest benefit to describe the different types of artificial intelligence application and systems being designed and built. The index is aimed to help those researching and developing artificial intelligence algorithms, topologies and applications, in describing the capabilities of the technique, and essentially to make it easier to compare methods in terms of their abilities.

Terminology

Some terminology and definitions used throughout this article.

Natural Intelligence
I will not use the term biological intelligence, but rather prefer the term natural intelligence or naturally evolved intelligence to refer to animal and human brains. This is because carbon based science in the form of, for example, genetic engineering and synthetic DNA, is touching on the realms of biological sciences and I wish to make a distinction between this type of engineering from that of natural creation.

Advanced Intelligence
This is the term used to describe artificial intelligence systems that are yet to be designed or built, that progress towards the achievement of super intelligence and beyond.

Collective Intelligence
Demonstrating human level intelligence in multiple domains, as if you had a room full of human experts together having knowledge on different subjects. This level and diversity of knowledge has previously been referred to as a polymath when demonstrated in a single person.

Task
Refers to a challenge requiring intelligent actions related to a specific application and domain.

Application
Refers to the display of intelligent behaviour for a particular task or tasks within a specific domain. For example playing chess. Essentially an application of intelligence.

Domain
Refers to an application area or subject. For example self-driving cars is one domain. Understanding all languages is another domain.

Entity
An intelligent actor (machine intelligence / robot / software agent) or being (human or animal). Natural or Artificial based Intelligence which delivers an intelligence application to a domain.

Model
An internal knowledge representation built up to help solve a given task or tasks.

Before I detail the continuum of intelligence itself, a few topical areas related to parts or all of the levels need to be covered first. A few concepts grouped together under the topic of Information Processing is first, followed by the much more controversial topic of Consciousness.

Information Processing

Here are some fundamental concepts that I believe are key for our understanding of the advanced development of artificial intelligence.

Data - Information - Knowledge - Wisdom. This represents not only how raw data is turned into useful insights and decisions, but illustrates the layered approach to processing data and information, turning large quantities of data into more refined, compact and useful information. This information is then further processed and potentially combined with other information to create insights and knowledge. This knowledge can then be combined and built up into a store of wisdom. The layered approach and the data volume filtering are key concepts that I wish to highlight here, both are fundamental concept for advance AI.

Substrate-Independent as termed by Max Tegmark, is a fundamental concept. Allowing the underlying methods and approach of the implementation of a computational or information processing task to be independent of the actual computational task. For example, a given sort algorithm does not know or care if it is running on a Windows, Linux or a Mac machine. This argument can be extended to cover the computations and information processing occurring in natural or artificial intelligence, the medium by which the computation occurs does not matter.

Church-Turing thesis is a hypothesis about computational functions. “Philosophers have interpreted the Church–Turing thesis as having implications for the philosophy of mind. B. Jack Copeland states that it's an open empirical question whether there are actual deterministic physical processes that, in the long run, elude simulation by a Turing machine; furthermore, he states that it is an open empirical question whether any such processes are involved in the working of the human brain.” [22].

There is some work on hypercomputers and super-recursive algorithms that are able to solve so called non-computable functions, however this research is currently not widely accepted. Let us remain optimistic about the workings of the human brain being composed of computable functions.

Consciousness

This is a very controversial topic. With hugely differing opinions on what consciousness is, and if it is possible to build an artificial intelligence that not only acts consciously but actually is conscious. I want to start this by stating that I completely believe that creating an advanced artificial intelligence that delivers the capabilities outlined by many of the later levels of the continuum detailed below, will have to also deliver a form of consciousness. As with all inventions, initially it would be crude and partial, making it seem as if it is just acting with a conscious but not actually having a conscious, and initially this maybe the case, but over time, I expect the capabilities to improve and deliver full consciousness. I propose, that to deliver the capabilities of advanced intelligence will also, by default, deliver a conscious entity, you can not have one without the other. Some believe that computations alone can not produce consciousness, I believe complex information processing and computations are the essence of consciousness.

“consciousness is a direct consequence of advanced information processing”

History has shown us that whenever we don't understand something we hold it in very high regard, thinking of it as magical and mysterious, but once we understand, it becomes known and simple. This is common place in many subject areas, and certainly has happened with previous AI techniques and approaches. We are experiencing this with the topic of consciousness at the moment, potentially making it more special or unique than it actually is.

Consciousness, like Artificial Intelligence itself, suffers from not having a single globally accepted definition. The reason for this, is certainly partially to do with the fact, that consciousness covers a multitude of capabilities, from internal thinking, being self aware, having subjective experiences, …

Some would argue that an entity needs to have the capability of language verbalisation in order to have a conscious, and would therefore rule out most of the animal kingdom from being conscious. I assert that this argument is flawed, some mathematicians and physicists have stated that they initial think visually, and only when a new thought is fully formed do they convert it into language. Penrose [23] amongst others, gives arguments and examples to support animal consciousness. Not having a vocal cord seems to be poor reason for excluding the possibility of consciousness in animals.

We also know that when we start to learn a new task or skill, like driving or skiing, we use our cerebrum and focus very hard consciously. But once a skill is learnt, it gradually becomes second nature, requiring us to “think” less about performing the task, as the processing for the task moves into the cerebellum. For me this is key evidence for the layered architecture within the brain, which map to varying levels of consciousness.

I agree with Max Tegmark, who in his book Life 3.0 [21], states that consciousness is substrate independent. For me its not just consciousness, its the entire workings of the brain. The Anthropic Principle [26] in both its weak and strong form, highlights the relationship between consciousness, physics and its place in the universe. The integrated information theory by Giulio [27,28] argues that a conscious system needs a high integration of information processing, and while I agree with elements of this, I believe it is less about high integration and more about Data-Information-Knowledge-Wisdom paradigm that uses information in a layered approach as part of more and more complex processing.

My thesis is that consciousness is a direct consequence of advanced information processing, combined with multiple levels of computational subsystems that deliver a variety of outputs, and is certainly reproducible as a computational simulation. Many of the later levels of the continuum of intelligence cover aspects of capabilities we attribute to consciousness.

Personality & Emotions

Personality can be considered to be the set of habitual behaviours, cognitions and emotional patterns that evolve from biological and environmental factors [15]. As with AI and consciousness, there does not seem to be one widely accepted definition of personality. However, most research and theories on personality seem to agree that its a combination of motivations and cognitive interactions with ones environment.

The Temperament and Character Inventory [17] is an inventory for personality traits, which can give a guide to the range of behaviours that need to be considered to produce an artificial personality. While all personality traits will have an indirect impact on the interactions with other entities, the cooperativeness trait is the most interesting, as this seems to directly deal with interactions with other entities, and the aspects of this trait that I call out for special attention, is that of Empathy and Compassion, as these require an understanding of another entities situation and emotional state.

Exploring in details the complexities of personality is beyond the scope of this article, but I will include more in my book. For now I only need to acknowledge that personality is a collection of

cognitive functions, and that creating an artificial entity that exhibits a range of behaviours that would generally be accepted as a display of personality is part of the journey towards advanced intelligence.

The Pardoe Index of Intelligence

We know from looking at animals and humans, that there are obviously different levels of intelligence, but we can also see there are most certainly key characteristics that are exhibited by all sentient beings. It is this fact that should actually help us define intelligence, but acknowledging that there wont be a single definition, that, in one sentence can easily characterise all the aspects that we see in intelligence forms of life.

One of the challenges for creating a definition and thus a measure of intelligence, is that many different aspects of intelligence maybe somewhat independent and developed in parallel.

So, to put some standard measures around the concept of intelligence, I believe the most useful way to to think about this continuum is in the form of levels or an index. Starting from simple displays of intelligence to the ultimate levels of super-intelligence and a technology singularity.

This index will allow the industry to track our progress over the next few decades, showing how we are building more complex and comprehensive technologies, algorithms and platforms that are able to exhibit certain aspects of intelligent behaviour.

It should be noted that while many of these levels are ordered in what might be considered a logical and progressive way, with one naturally following another, it does not follow to be the case for all levels, and as such some might start to be evident in an AI system before other lower levels. This is perfectly acceptable and expected. Also some levels encapsulate very complex capabilities, that may not be possible to fully demonstrate initially, with progress being partial. Again this is totally expected. Some levels are closely aligned, potentially overlapping, others show advancements of earlier levels. This is in part why I have called this a continuum, there is so much entanglement with many of these levels, it truly shows the beauty and complexity of the most amazing object that we know, the human brain.

In my book, I will develop these conceptual levels, allow us to have some quantifiable metrics and score for each AI system. I believe for each index, we would be able to score a particular application from 1 to 10, giving us a total score out of 180. where 0 shows no intelligence and 180 is a fully functioning super-intelligent singularity demonstrating god-like intelligence. For now, I want to focus on the actual index definitions.

P1 - Narrow Single Application Intelligence

A Single Narrow Application, essentially only performs one task. For example language translation from one language to one other, predicting a specific stock price, or providing recommendations for shopping items. There are already many examples of such a capability with artificial intelligence techniques, ranging from rule based decision trees to multi-layer neural networks. We should note that the level of accuracy achieved by any AI application or system, or their inherent biases are not specifically factored into this index, it is expected that the skills of the data scientists and engineers will ensure the optimum achievable performance of the application. Biases in algorithms and datasets are a problem which have a number of strategies to solve, and is outside of the scope of this discussion, as it can be considered a constant issue throughout. This would be the level of the index covered by the term Weak or Narrow AI

P2 - Single Domain, Multiple Tasks

An application within a single domain. Leverages an internal model or map for that given domain. For example language translation between three or more languages or image recognition for the application of driving. Still Weak or Narrow AI, but more advanced in its approach than the previous level, and more general in its application. The main differentiator between this level and the previous level, is the development of an internal model that maps well to the domain. An interesting example here is the language translation, where it was discovered an internal mapping between the different languages had been formed that surprised the engineers and scientists involved. Development of these internal models are an absolute necessity for advanced intelligence and we should not be afraid of these being developed, even if we are unable to fully understand them.

P3 - Single Domain, Multiple Applications

Capable of applying learnt knowledge across applications within the given domain. So able to play any type of game; board games, arcade games, strategy games, roleplaying games. Or being able to perform self-driving on any type of wheeled vehicle. Maximises the benefits envisioned with transfer learning.

Here the internal model may exhibit what we consider to be strange properties, for example, chatbots speaking a strange language that is not comprehensible to humans. These is an example where the internal model doesn't easily map to something we would instantly recognise in the real world, but, does not make such a model invalid or incorrect (which has happened with such chatbots being turned off for speaking their own language. For me, this is an obvious thing to happen, we should not be afraid of it happening, but recognise this is a step along the continuum of intelligence development).

P4 - Adaptation

As Stephen Hawking once said, "Intelligence is the ability to adapt to change" [17]. Adaption can come in different forms, from that of continuous learning and seeing new patterns in more recent data, to more dynamic and reactive adaptation that relies on the application of game theory, strategy and tactics.

Strategy and Tactics / Use Game Theories

Ability to negotiate, collaborate and lie to maximise its own chances of success. Demonstrating strategy and tactics. Can work as a team or an individual to maximise benefits. This can be thought of as the first stages of being aware to the point of knowing that there are options to approaching the task, and that there are multiple actors in play.

Online and Offline Learning

Ability to learn from its mistakes and learn new things is also part of adaption. The offline learning might be considered, from a nature perspective, encapsulated in the act of dreaming (or maybe dreaming is the consequence of offline learning/training). This can come in the format of feedback from external sources, or more gradual changes from the training data, as the system is frequently re-trained to ensure it picks up this drift in the data.

P5 - Aware of its Environment (Local and Global)

Self-aware of its environment. Understanding the environment and how that effects its own tasks. Demonstrating consciousness at some degree of completeness.

This is going to be a particularly controversial level, as I know there is alot of discussion in the literature about this topic. Arguing if consciousness is even possible with artificial intelligence regardless of the implementation method. Rather than get into deep arguments about this, I will simply state that one of the problems with many of the arguments is the lack of definition of what they mean by consciousness**.** And without that it is simply pointless having a discussion. So lets

start with that. And in actual fact I have broken the definition of consciousness into several parts, with higher order of consciousness being covered in levels P6 - P12. The awareness elements of consciousness are covered in this level. By aware I simply mean having some map of the environment. And with everything in this article there are different levels or degrees of awareness that we must recognise.

Deep Blue and Alpha Go algorithms where aware of the virtual boards on which they were operating on, but did not understand that the game was actually being played in the physical world, in a room, with an audience, in a building, in a town or city, in a country, on planet earth, within the milky way galaxy, etc. But then one could argue it didn't need to know all of this. It might be useful to know it was playing a real game, against a real person, against the world champion in actual fact. But is it important it knows what city it is situated, would that alter the way it would play the game? Maybe, maybe not. The point is there is multitude of different scope and size when we look at the environment in which an entity is self aware of.

Also we should note, that our intellectual understanding of an environment can change as we learn more. As humans, many years ago, the leading theory on our world environment was that the world was flat. We now know this to completely incorrect, but what this means is our model of the environment changed. We were still as self-aware as before, but our view on the environment has changed.

Anyway, getting back on topic, I believe that an intelligence that can demonstrate an understanding of its immediate environment is an important step towards full intelligence.

I also believe that once you have an intelligence that is truly self-aware, it will want to expand its map of the environment.

Being aware of an environment is only part of the puzzle of this level. It must understand how the environment might change factors that effect the task it is performing, allowing it to continue to adapt its approach based on changing environmental conditions and factors.

P6 - Self Aware

Self Aware is a natural progression from being aware of the environment in which the entity is within. Understanding one’s own place within that environment, Understanding who and what you are and how you can affect the environment which you in, are key factors to being self aware. As with all of these levels, there are varying degrees of achievement here relating to different aspects of self awareness.

One of the most amazing things to see in nature is when a kitten first sees itself in a mirror. There is a period of time when it does not recognise what it sees in the mirror as itself, and starts to perform a dance to scare off the stranger. Eventually the kitten learns that the reflection is indeed a representation of itself and then starts to ignore the image (or atleast isn't threatened by it anymore).

To recognise oneself is the first stage, but to then to be able to correctly categorise oneself and recognise similar entities is the next stage of being self aware.

We can see in the development of baby humans, that their awareness of the environment, and awareness of themselves within that environment develops over time as their cognitive capability advanced in their first few years of growth. But we would also argue that the baby is conscious from birth, despite having very limited awareness.

P7 - Explain its Reasoning

To be able to explain its internal thinking or model (models) and to be able to reason and have a rationale for decision making. This is another key element of demonstrable consciousness.

Those developing these advance AI systems, actually want to understand how they are working and will no doubt continue to do so, and thus will naturally want to build the mechanisms that allow the rationale for decision making to be exposed.

But we must acknowledge that even humans are not always able to do this, using the term instinct or gut feeling to explain some thought making processes. This might be because some of the decision making process happens with our unconscious mind, making it more obscure to define. And maybe there is good reason for this that we don't understand. Maybe some decisions are not fully defined by a logical reasoning, and the emotional aspects of decision making are more difficult to describe.

While we seem to accept this in humans I believe it will be sometimes difficult to accept the same argument from our machine intelligence entities.

P8 - Cognitive Independence

To combine multiple communication methods (language / mathematics / music) and to demonstrate full human like cognition functions across the senses, motor skills (physical motion), emotions.

As with any system, input and output are key elements, without which it would be very difficult to fully function. Taking those inputs and outputs from simple binary representations of information, to be fully integrated with the physical world is going to be significant step in the evolution of artificial intelligence. This field is developing well with the various robotics initiatives currently in flight.

Enabling AI to build its own internal models for the various methods of communication is hugely important and we will no doubt see communications that interface with humans but also communication methods that only other AI can understand. There is an ethical issue here that no one has even thought of before (we have seen examples of chatbots speaking with each other in their own language, and the way we have dealt with this was to simply turn them off. This is not a sustainable approach, and actually demonstrates how scared we are of our own progress).

I would like to separate the development of advanced intelligence from that of mobility in the form of robotics and androids, however, it will be a significant step for humans to accept advanced intelligence by experiencing it in a familiar form, so the field of robotics will be an important technology running alongside that of AI. While we will experience all forms of robotics, and it is unclear at the moment if human like androids will be widely accepted, it is a current field of research. However, I am reminded of a recent experiment in which two teams of humans augmented with a robot helper had to work on a team task. The team with the robot that made mistakes was considered more of a team-mate by the humans than the robot that performed perfectly. I guess no one likes a know-it-all.

The field of robotics is developing strongly by working in partnership with AI advances. Learning to walk, run, jump, recognise objects, use its robotic hands to pick up a multitude of different shaped objects just via trail and error, and even catch balls thrown towards it. We must remember that it isn't the robot that is smart, after all, its just a mechanical machine, its the AI brain that controls it that provides the human like capabilities.

P9 - Personality, Emotions, Empathy & Compassion

Giving our artificial intelligence applications a personality will make them individual and unique. But do we want our AI systems to define their own personalities, or have them pre-defined or pre-programmed. Do we want our personal assistant to be moody or angry?

Going into the complexities of personality for the purposes of this article is not going to be possible. However we acknowledge that being able to simulate personality in a way that provides unique and individual personality without developing extreme behaviours will help with social engagement and acceptance of advanced AI agents.

Personality is a reaction to a defined set of emotions. Different people can see the same image or video and it will make them react in different ways and at different scales. No doubt this is a combination of our current emotional state combined with a defined emotional reaction to input based on past experiences. A complicated mix that ultimately will define a response that is then perceived as a personality or emotional response.

One may ask why do we need such capabilities in our AI systems. And for many we probably don't. But for robots / androids that are regularly interacting with humans, having a personality that can make it easier to interact with humans is going to help with the integration between the two forms of intelligence.

To show empathy and to understand other entities situation in the given environment. To know right from wrong. Able to form relationships and interactions with other entities. To demonstrate emotions. All of these are going to be hugely important as we see more and more AI applications, agents, systems and robots enter our personal and professional lives. We will need such AI to be able to empathise with us, to adjust its approach towards us based on the specifics of our situation.

P10 - Self Governing

To show empathy and to understand other entities situation in the given environment. To show compassion for another entities situation. To know right from wrong. Able to form relationships and interactions with other entities. To demonstrate emotions. This is rolled up into the demonstration of personality, however, how the entity reacts to situations, needs to be regulated. In human behaviour, we sometimes refer to it as 'common sense'.

Here we demonstrate higher order consciousness by exhibiting a social and moral compass. To understand cause and effect.

Without getting into the details of how this type of intelligent capability might be implemented. This is where we might think of the laws of robotics that Asimov defined, and opens the debate as to how these "rules" of self governing should be encoded. Should some of them be hard-coded, never to be changed or removed, while others can be added over time. One might argue that humans know right from wrong, and usually follow these from a morale and social perspective, but these are either not hard-coded or can be overridden depending on the circumstance, situation and/or the decisions made by the individual. Do we allow our AI and robots the same potentially deadly capability to decide when to follow the rules or not?

P11 - Self Learning

To understand the current limits of its own model / thinking and be able to expand its knowledge which in turn improves it's models. We currently have systems that use online or near-line training to adapt to changes in the underlying data and ensure the model is performant. We are also starting to look at modifying the topology of the network of neurons before and during training.
A human brain adds around 1,000 neurons each day, allow us to continue to learn new things, save new memories, alter our thinking or repair/replace bad neurons. We have only just scratched the surface in this particular area, but there is lots of interesting advancements already.

This will be a major capability required to achieve a technological singularity, but here we are only talking about adaption and evolution that is controlled and constrained by our own human understanding.

Being able to extend existing models, making them more complex or even simplifying them depending on the circumstances, is an essential part of continued learning, being able to essentially replace one model with another more accurate version, is key to self learning capability.

P12 - Self Doubt / Challenge its Models / Belief System

To have an element of inbuilt doubt that acknowledges that the application may not be in command of all of the facts that apply to the given situation. This is what Stuart Russell refers to, and suggests we need to factor into AI in order to safe guard the human race from potential extinction events caused from an AI thinking it is doing the right thing, but not understanding the bigger picture, or have all the facts at its disposal.

Includes potential for spiritualism and religious beliefs, which itself opens up a huge topic of discussion as will an artificial intelligence of human like capabilities see humankind as its god or develop beliefs aligned to human religions. Or does the development of advanced intelligence not need the support of a belief system.

There has already been the establishment of the first AI religious group called the Way of the Future who's purpose is to develop and promote the realisation of a Godhead based on artificial intelligence [12], will advance AI worship an AI based god?

This is a hugely fascinating area that until now has not really be discussed that much, but I would suggest that as we develop more complex AI, this area of study will increase as the need to support such capability increases.

P13 - Internal Self-Modifying / Evolving / Self-Design

We already have methods that modify the topology of the neural network, pruning neurons for example. Taking this further, we will construct AI systems, that design optimum architectures and learning algorithms that maximise the capabilities of AI applications.

This self-design will form the foundations required for the singularity, but at this level will be simple methods and approaches, and will be unlikely to involve dramatic changes or complete re-design.

This level of development might be considered a horizontal level, that is incrementally improved as we advance across the other levels. It will be matured as we head towards level P17 - The Singularity.

Where natural intelligence uses the DNA genetic mechanisms of mutation and crossover to gradually evolve new capabilities and functions, our advanced intelligence will apply a much faster method of evolution of self-design. The ultimate progression of the self-modifying or self-design capability will only be evident in the singularity level, but will be the most powerful form of evolution that we will ever encounter.

P14 - Single Domain of Expertise / Human Intelligence

For a single field of expertise, with significantly broad and deep knowledge, being able to better a human being is a major milestone. How we measure this is going to be very important. As an example, there is a lot of focus on building self driving vehicles at the moment, and while we are able to train a system that has technically more driving miles “experience” that any human could

acquire, we don't have a single entity that can fully drive any car, lorry, motorbike, etc. So while we are making amazing progress, we are still a very long way from achieving a close to human capability with driving. And here we should make the distinction that we should set the bar high, and it should be an expert human in comparison, so in this example, a single human that is able to drive all types of vehicle, from the largest truck or lorry to the smallest of motorbike.

P15 - Many Domains of Expertise / Collective Intelligence

While we have a few examples of humans being experts in multiple fields, referred to as polymath, this is the exception not the rule, and as the universe of our known knowledge is increasing at a tremendous rate, it is becoming more difficult for a single human to achieve polymath status. Hence the term Collective Intelligence, referring to the intellect of a room full of human experts of different fields of knowledge.

Able to combine expertise across several related domains and having those domain models seamlessly integrate giving rise to true collective intelligence.

This will be a wonderful milestone for humans, as we will have systems that can provide amazing insight into subjects, that might take humans much longer to develop. Help us to create new medicines to cure illnesses, create new molecules and materials, design new products, deliver new services and produce new art. All of this and much more will be possible. And actually we have seen repeatedly that good things happen when we cross subject borders and bring expertise from two areas together or take discoveries from one area and apply them into another.

P16 - All Domains of Expertise / Partial Singularity

Able to combine expertise across a multitude of disparate domains and having those domain models seamlessly integrate giving rise to true singularity.

At this stage we get to the point that the AI is able to understand the fields of technology and artificial intelligence, enabling it to modify itself, but much more than will be achieved in level 11. Level 11 is only going to be focused on limited improvements. Here the changes will be driven by truly understand the subject matter, what has been currently achieved and what is possible.

The singularity will not only deliver rapid technology change, some of which will enable it to improve itself, but it will make advancements in all topics and subjects it understands. The rate of change and advancement will be, to humans, astonishing, and we will truly struggle to keep up with understanding what is being suggested. Potentially we will have to accept changes that we just don't comprehend. This will be a significant milestone in human development, and no doubt will not come easy. As for centuries we have been comfortable in the position of most intelligent entity in the world. To give this position up, and trust in the machines that we have built will be a huge leap of faith.

P17 - Singularity / SuperIntelligence

Part of the Singularity is the ability for continuous improvement, self-modification and redesign to facilitate improved performance and abilities.

Natural intelligence in the form of the brain has evolved over millions of years, and currently takes a number of different forms, with wide ranging brain size and number of neurons across different species within the animal kingdom. Evolution with technology has the potential to occur much faster, with “new versions” of both the hardware and software able to happen exponentially quicker than with natural evolution. Being able to design itself, creating improved versions of itself in one generation, is immensely powerful, and has the potentially to completely run away from our own understanding. For me one of the most interesting questions here will be what medium the entity

chooses to built itself, will it stay a silicon based entity, will it migrate back to carbon, use a hybrid approach, or selection another technology as yet unknown.

Another element of the singularity or super-intelligence is that of making dramatic inferences and advancing knowledge beyond what we would consider to be a normal or even exponential rate of advancement.

A final aspect of this level, will be our own incomprehension in both its findings and its fundamental understanding.

P18 - God like Intelligence

Taking the super intelligence further, it will develop so fast and so complex, that it will supersede our own cognitive understanding, both of how it is working internally and its understanding.

“When the intelligence becomes so advance, that we, as mere humans, are completely unable to understand it; we will see it as totally mysterious and magical.”

We will see the things that it does as miracles, as master of everything it does. We are most likely to hold this entity in the same light as a God.

While many people will find this idea most disturbing, even blasphemous, this is I believe, the last level of the continuum of intelligence. At this point, the entity will be all seeing and all knowing, and will have achieved the most extreme level of advanced intelligence.

And just maybe this is when the universe will start another cycle of creation.

Summary and Conclusions

Until now, we haven't had a way to properly measure the progression of our efforts towards advanced intelligence. The Turing test gave us a way to measure a very specific milestone along the continuum of intelligence, but fails to give us a way to track our progress either before or afterwards. The Pardoe Index, in its current form (as given here) is very high-level and coarsely defined. The index while ordered in some logical progression, it is acknowledged that developments will happen across the index at certain degrees of completeness. I plan to expand in much more detail on each index level, and give a finer grained definition of each level, that will allow us to determine if a particular AI system is fully compliant with any given index level, watch out for my book of the same title to be published in 2018.

The true purpose of life and the universe, is the advancement of intelligence.

The journey to advanced intelligence, during this golden age of the algorithm, is going to be one of the most exciting periods of human history, with huge positive potential if we get it right. Let us all hope that we demonstrate our own intelligence to consider all aspects of advance intelligence entities (before we switch them on) and that they show us more respect and compassion than we have shown other entities of lower cognitive abilities in the past.

If we do not embrace and integrate with the technology driven advanced intelligences of the future, we seriously risk becoming as extinct as the Dodo.

Notes to Reader

I hope you have enjoyed reading this article. I welcome your feedback and suggestions for improvements. While this article will form the basis for my book by the same title, I expect to include a lot more substance and background materials as well as expanding on the levels themselves to allow for a more quantitative measurement.

Please send all feedback to andypardoe.com/contact/

If you would like to be notified when the book is available, please sign up to my newsletter at andypardoe.com/newsletter/.

Appendix

Related Topics
During the research and writing of this, a few topics have manifest themselves which while I have not include in the main index, require some mention.

Dreaming
What is the true purpose of dreaming? Most if not all natural intelligent entities appear to need to sleep. [while many animals exhibit sleep with the whole brain entering a sleep cycle, some dolphins for example are able to “shut down” half of its brain into a sleep mode, while the other half of the brain remains active as normal]. No doubt part of this is to rest and repair the body. Is dreaming purely the result of the brain having limited stimulus from its normal inputs (senses and nervous system), or is it an important cognitive process that all natural intelligence entities have?

One must also consider that nature of dreams and the action of the mind to add neurons and build connections during this “offline” period. One might equate this to batch based learning, verses online or near-line learning that we are familiar with as data scientists. I am keen to identify all the aspects that will be required for true intelligence. Consciousness is one obvious aspect that is required, maybe the second required aspect of intelligence is that of dreaming (offline learning).

Simulated Behaviour verses Actual Behaviour
For a computer scientist, this is an interesting topic. When does a simulation of something actually become the real thing. For humans, we know when we are faking an emotion, compared to the real thing. The difference between acting and reality. To quote shakespeare, “the world is our stage”. So when does simulating an action, behaviour, or emotion become real? I believe the answer is simply when its complete and feels real. The substraint-independence rule applies here too. We don't need a biological eye to see, and we don't need a biological brain to make decisions or run calculations.

Carbon-Silicon Hybrid Intelligence Augmentation
One way in which humans may avoid extinction to advanced artificial intelligence, is to become integrated with it, a form of cyborg, combining the best of nature and technology together. This is a view shared by many leading AI researchers as one approach to avoiding being superseded by AI and potentially also avoiding the potential threat of being exterminated by super-intelligence AI as the human’s will, with this hybrid augmentation, retain control over the advance intelligence. [13]

A Diversity of Experts
It seems that the topic of the intelligence and the mind brings together experts from many different fields, including neuroscientists, physicists, mathematician, phycologists, philosophers, computer scientists, linguists, biologists, and no doubt many others. I have been particularly intrigued with the works of many physics and maths experts on the topic of intelligence. The emergent phenomena from physics seems to warrant them with the ability to claim ownership of any discovery, as it all boils down to particles and energy. I am reminded of an episode of the Big Bang Theory where Sheldon and Amy are arguing about this very topic, and Amy reminds Sheldon that all physics theories are created by the human brain and therefore the domain and creation of neuroscientists. I wish to follow a similar argument and conclude that the best commentators of information processing and computation, regardless of its form, should be from computer scientists.

Darwin and the Survival of the Smartest
Darwin was wrong, atleast partially. While survival of the fitness works with low cognitive capability species, as the dominant factor then becomes “fit” to the environment. With an abundant environment many species survive, with a changing environment or one with scarcity, some win and others lose, but its as much luck as judgement. The true survivors and ultimate winners, are those who adapt to changing environments quickly, those that exhibit intelligent behaviours. And so

its the “survival of the smartest”. Once can argue that “fit’, on average, could mean those best able to adapt, but I think Darwin’s interpretation of fit is actually more about alignment to the environment conditions than immediate adaptation.

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