Abstract

In this paper we consider the nature of the machine intelligences we have created in the context of our human intelligence. We suggest that the fundamental difference between human and machine intelligence comes down to embodiment factors. We define embodiment factors as the ratio between an entity’s ability to communicate information vs compute information. We speculate on the role of embodiment factors in driving our own intelligence and consciousness. We briefly review dual process models of cognition and cast machine intelligence within that framework, characterising it as a dominant System Zero, which can drive behaviour through interfacing with us subconsciously. Driven by concerns about the consequence of such a system we suggest prophylactic courses of action that could be considered. Our main conclusion is that it is not sentient intelligence we should fear but non-sentient intelligence.

1 Introduction

The narrative for the arrival and nature of artificial intelligence fails to take into account fundamental differences between the intelligence of humans and that of computers. One result is a conflation of characteristics which are likely peculiar to humans with capabilities that are only associated with machines.

In this paper we cast machine and human intelligences within a common framework. We base our ideas on considering fundamental characteristics of an intelligence, such as its ability to compute information versus its ability to communicate information, from that firm basis we will speculate as to why human intelligence is like it is, and what differences are occurring in the way machine intelligences are evolving.

Our conclusion is that it is not sentient artificial intelligence that we should be afraid of, in contrast the real challenge is understanding the pervasive intelligence, and specifically the form of pervasive intelligence that is already within our capabilities.

In this paper, we will frame our arguments about some fundamental properties of intelligence. We will try to be general, but to do so we must first be restrictive.

Let us think of intelligence as a property associated with an action, within a defined context. We judge some actions to be more intelligent than others, so there is a spectrum of intelligence.

To quantify the intelligence of actions we need to have an understanding of the goals of those actions. If two agents have the same goal, and the same information about their environment, then one agent could be judged as more intelligent than another, if it achieves that goal by deploying less resource. Where, for example, resource could be measured in terms of available energy.

Imagine you have the goal of recovering an object from a known position in an environment. Perhaps you have accidentally kicked a ball over a fence. Under our definition, it would be more intelligent to take the most direct route to retrieve the ball, rather than a circuitous route, because the direct route uses less energy. But what if environment was hostile? What if the ball had landed in the garden of an angry neighbour. Perhaps now it would be more intelligent to observe the environment first, or to take a circuitous route that provides a degree of cover. The possibility of invoking the neighbour’s anger may result in greater energy expenditure over time. Much is dependent on the goal (ball retrieval) but also the context. Hence,
to determine which action is best we now need to have a model of our environment. A way of predicting
the consequences of our actions. So although the definition is fairly simple, selecting the most intelligent
action before events have unfolded can be very challenging.

While we’ll think of intelligence as primarily the property of actions given a defined goal within a
given context, we will also use the noun in the form “an intelligence” to refer to an entity that is capable
of performing goal driven actions based on information

2 Some Necessary Components

Intelligence requires prediction about the environment and its possible evolving states. They are, thus,
essential to choose actions to achieve our goal with the minimum energy outlay. In other words, the
ability to predict is fundamental to the ability to plan. Therefore, rather than focussing on the details of
planning, we will start by considering the requirements for prediction.

The concept of a predictive intelligence was expressed beautifully by Laplace.

We ought then to regard the present state of the universe as the effect of its anterior state and
as the cause of the one which is to follow. Given for one instant an intelligence which could
comprehend all the forces by which nature is animated and the respective situation of the
beings who compose it—an intelligence sufficiently vast to submit these data to analysis—it
would embrace in the same formula the movements of the greatest bodies of the universe
and those of the lightest atom; for it, nothing would be uncertain and the future as the past,
would be present to its eyes.

Pierre Simon Laplace A Philosophical Essay on Probabilities 1814, Translated in 1902 from
the Sixth French Edition by Frederick Wilson Truscott and Frederick Lincoln Emory [1].

This idea is known as Laplace’s demon. Laplace’s demon underpins a concept known as the mechanistic,
or clockwork, Universe. A world in which everything is predictable. In practice there are three obstacles
to overcome in achieving it.

1. . . . an intelligence which could comprehend all the forces by which nature is animated . . .

This is the modelling problem.

In practice we don’t have full knowledge of the Universe, we use models. A model is an abstraction
of the real system. One which represents particular aspects of the system for us. The word also
implies an idealization of the real system. We cannot operate directly on the real world for our
predictions. In practice we operate with idealized version.

2. . . . and the respective situation of the beings that compose it . . .

This is the data problem.

The data problem is that even if we have a functional model of how the our universe works, to make
predictions of how the universe will evolve, we have to understand what state it’s in currently. For
example Newton’s laws tell us how a ball will bounce, but to make predictions of where it’s going to
be next, we need to know where it is now.

Unfortunately, we almost never have complete data, indeed our challenges are characterized by
missing almost all data, almost all the time. Intelligence has to perform well from a position of
ignorance about aspects of the system.

3. . . . an intelligence sufficiently vast to submit these data to analysis . . .

This is the computation problem.

Even with full data and a complete model, predictions may be intractable because they can involve
an exponentially increasing number of computations.

Ironically, despite the power of this view and the extent to which it captures even a modern under-
standing of intelligence, Laplace was actually describing his demon as a straw man. The quote is taken
from Laplace’s essay on probabilities. Laplace knew that combining these three elements was not possible.
In a complex Universe such as ours we cannot hope to resolve these requirements, the modelling problem,
the data problem, and the computational problem. Laplace’s idea was to use probability to deal with our
ignorance. The universe is laced with a significant doses of uncertainty. We will not have full data, we
will not have an accurate model and, most of the times, we will not have the necessary computational
power to resolve our predictions in a timely manner. So these three pillars of intelligence need to be
deployed with a dose of skepticism about the predictions they make.
2.1 Communication

Model, data, computation, and measured skepticism are four components of intelligence. However, there is yet a fifth aspect that is missing. That is the communication of the results of such an analysis, or partial analysis. The ability to share information to ensure that a community of collaborating entities can take intelligent actions. Communication is a side effect of our definition of intelligence. It is a case of circles within circles. It is a way of acquiring more data, sharing, compute, and better modelling the environment, because those entities with which we communicate often perform changes in our environment. If they themselves change the environment, and we have the ability to understand their intent, then any communication we receive from them will be an aid to decision making.

Even a simple intelligence, which doesn’t communicate explicitly, will communicate through its observable actions. This communication may begin as uni-directional, but if we respond to our understanding of that intelligence with actions of our own, we are also providing information about our own intent. If the other-intelligence becomes sophisticated enough to attempt to interpret our actions, then a form of bi-directional communication has already been established.

Of course, once bi-directional communication is established, then increasing the rate of communication could also improve our ability to understand intent, and therefore allow more intelligent actions.

2.2 Embodiment Factors

Computation underlies prediction. Communication aids in acquisition of data and refining prediction. We will now argue that a fundamental property of any intelligence is the ratio of its ability to compute to its ability to communicate. Without the ability to communicate, an intelligence operates as the proverbial falling tree, it makes no sound. Such an intelligence would be totally locked-in.

A locked-in intelligence is embodied, it is constrained. It may have the ability to compute many predictions and resolve a course of action, but it does not have the ability to share all those predictions with the outside world. The nature of that intelligence is therefore more embodied. Conversely, if an intelligence’s ability to communicate is high, if it can share all its thoughts and imaginings, then that entity is arguably no longer distinct from those which it is sharing with. It could be thought of as merely a sensor. For high ratios of compute to communicate, we have high embodiment, we therefore define this ratio as an intelligence’s embodiment factor.

\[
\text{embodiment factor} = \frac{\text{compute power}}{\text{communication bandwidth}}
\]

3 Humans

Let us now compare humans and computers using the embodiment factor, we start with the human.

For humans, our maximum rate of communication via talking or reading has been estimated to be 60 bits per second [2]. In contrast, a modern computer can exhibit communication rates measured in gigabits per second or around a hundred million times faster.

To compute our ratio, we now need to estimate the computational power of the human mind in bits per second. This is hard to estimate. But as a proxy, let’s consider estimates of how much computing power it would take to simulate a brain. One estimate from Ananthanarayanan et al [3] suggests that it would require over an exaflop to perform a full simulation of the human brain. That’s around the power of our fifty fastest super-computers today. A desktop computer has much less power, typically around 10 gigaflops.

---

1 Here we are using measured skepticism to refer to the ability to deal with uncertainty in a balanced way, an acceptance that the picture may not be complete. Absolute skepticism would be the refusal to accept any information we are given, i.e. a complete lack of trust in the data or the model.
2 Of course, here we are presuming that there are other entities capable of receiving and interpreting this communication.
3 Here we are neglecting visual forms of communication, but this estimate will serve for our rough purposes.
4 Here we are using bits in the Shannon information theoretic sense, which defines one bit of information is the amount of information you gain from knowing the result of a fair coin toss.
5 A flop is a computer-centric way of measuring computation. It stands for a floating point operation. In other words a computation on a floating point number, which in many modern representations contains 64 bits. An exaflop is \(10^{18}\) flops.
6 As of today, the world’s fastest super computer is operating at around 34 petaflops by some benchmarks.
7 And yet, we cannot simulate the brain, that is because we have not solved the modelling problem, we do not understand yet how the brain works.
The embodiment factor of the computer is around 10 whereas the human is around $10^{16}$. Embodiment factors mean that we can only distribute an extremely small fraction of what we compute. In the table we use rough order of magnitude approximations to the figures we’ve mentioned in the main text.

Table 1: The embodiment factor of the computer (around 10) vs the human (around $10^{16}$). Embodiment factors mean that we can only distribute an extremely small fraction of what we compute. In the table we use rough order of magnitude approximations to the figures we’ve mentioned in the main text.

|                      | Machine        | Human          |
|----------------------|----------------|----------------|
| compute              | ~10 gigaflops  | ~ 1 exaflop?   |
| communicate          | ~1 gigabit/s   | ~ 100 bit/s    |
| embodiment factor    | ~ 10           | ~ $10^{16}$    |
| (compute/communicate)|                |                |

In terms of our ability to share our states of mind, to share in all our motivations and whims, we are extremely limited. Our actions can be observed but we are unable to communicate all our thoughts.

As an analogy, we could think of human intelligence as an extremely powerful engine. We might think of it as a Formula 1 racing engine. But, we can’t communicate all our inferences. So don’t think of us as a normal F1 racing car, but replace the normal oversized tyres with tyres of the width of bicycle wheels. Our limited ability to communicate means we cannot deploy our power on the track directly. We must demonstrate extraordinary control in deploying that power if we are to make our communication effective. Imagine the dances such vehicles would perform as they completed laps of the cognitive circuit.

Figure 1: Marcel Renault drives his 16 HP 650 kg Renault car in the Paris-Madrid race on May 24th 1903. The car was thought to be capable of over 140 km/h. Three spectators and five participants (including Marcel) died during the race which was cancelled at Bourdeaux. Open road racing in France was subsequently banned.

3.1 An Intellectual Dance

Our power is intellectual power, and because of the vital importance of communication in intelligent decision making, it would make sense that intellectual power was also deployed in making the most sensible use of the low bandwidth communication we have.

The challenge is to make use of a limited resource (the bandwidth of our communication) to achieve our intermediate goal of better understanding the intent of different actors in our environment. This allows us to, in turn, select our own actions to better achieve our ends.

This is consistent with our definition of intelligence. The limited resource is now the bandwidth of communication channel. Intelligent use of that bandwidth involves deciding what to communicate and when to communicate it given our prediction and model of the environment and other agents in it.

For a community of embodied intelligences, the locked-in nature of their intelligences requires that each maintains an independent model of the environment: they do not have the bandwidth to access a communal model. If we think of these embodied models as an internalised film or play, then each of us develops the script of life with our own independent playwright and production crew. These scripts are
tailored to reflect our personal concerns and our personal desires. Each of us is a director. We can see our
independent self-models as stories with actors, and each actor maps onto a real entity in the world. The
storyboard is our circumstance. Within these models, all our friends and foes are accounted for. These
stories operate at an emotional level and a rational level.

In these circumstances, communication reduces to a reconciliation of plot lines among us. In the real
world, we express ourselves in many ways. Communication requires that each of us develop our own
plotlines according to how we see the real world evolving. We tune our plot lines to resonate better with
reality. And in that way, we are also ready to orchestrate our goals.

3.1.1 The Hot Drink

In March I had dinner with Beau Willimon, the playwright and screenwriter. We were talking about
communication. He described to me a scene. He told me that I had known that my partner’s mum was
seriously ill. He told me that I arrive home to find my partner sitting silent on the sofa. He told me
that as soon as I arrive I go to the kitchen and make my partner’s favourite hot drink. He described
that at the moment my partner hears the kettle boil, at that moment she burst into tears, because she
then knows that I knew what had happened. And she knows I am doing the thing she wants most, the
unspoken comfort of a hot drink. And she knows in a very deep way that I am close to her, and she
knows exactly what she had lost by losing her mother who was also close to her.

This scene can all be understood without a word of dialogue. Indeed the absence of dialogue is critical.
It makes it an emotionally powerful scene. The scene relies on each of us each knowing the relationship
between partners. It relies on each of us knowing, or at least imagining, how the loss of a loved one feels.
It relies on us having a personal narrative (or self-model) and a deep understanding of those who are
close to us. If we watch this scene being played on film, it effects us because even though it’s about other
people, we can relate to those people and their emotions. The depth and quality of the communication in
this scene comes through understating and understanding. By understating the interaction, by making
the hot drink, there is a demonstration that communication is not necessary, there is a demonstration
that the two actors are in tune, even without a word passing. The depth of understanding means the
actions can be simple, the mental equivalent of a parity check

8In technical terms a parity check is a simple check used to ensure that the message sent was the same as the message
received. It requires little information to encode (only one bit) but it gives confidence that the sender and receiver are aligned.

But the meaning is deep. These are the exquisite lengths to which we have been driven to overcome the bandwidth limitations we are faced with.

Another example is credited to Ernest Hemingway, the six word novel, “For sale: baby shoes, never worn”.

3.2 Self Modelling and Dual Process Theories

We do not understand how the brain works. So cognition is inscrutable for us. We do not yet understand
it in terms of its hardware (e.g. the interconnectivity of the brain, the connectome [4]) or its software
(e.g. the algorithms or principles by which it represents knowledge [6]). Therefore, for the purposes of
this discussion we will limit ourselves to analogy and fairly simple qualitative models of cognition. In
particular we will make use of dual process theories [7]. Dual process theories divide our cognition into
two parts. For the level of granularity we are considering in this paper we will conflate these different
analogies and models together. Stretching back we have Freud’s separation of our psyche into the Ego and
the Id [8]. Whereas more recently Daniel Kahneman writes lucidly about this separation in “Thinking
Fast and Slow” [9] where the processes are characterized as System 1 (the sub-conscious) and System
2 (the conscious). But they are often painted more colourfully through analogy, for example the social
psychologist Jonathan Haidt [10] refers to them as an elephant (System 1) and a rider (System 2). This
analogy is meant to reflect the fact that the sub-conscious (elephant) is more powerful and in control,
despite the fact that the conscious part (the rider) believes itself to be in charge. The sports psychologist
Steve Peters [11] calls them the chimp (System 1) and the human (System 2). Camerer et al suggest that
the human brain is just a monkey brain (System 1) with a press secretary (System 2) ) [12], an analogy
that captures nicely System 2’s role in post-facto rationalization. Even religious theories separate us into
the flesh (System 1) and the spirit (System 2) or the body (System 1) and the soul (System 2).

Each of these models indicates our characteristic of having a more base form of behaviour (System 1)
that is regulated, or justified, by our conscious selves (System 2). In the original German, Freud referred
to the psyche as the Es and the Ich, or the “it” and the “I”. Each of the analogies associates a more human
part alongside System 2 (the rider, the human, the press secretary, the “I”). Whereas the sub-conscious is
seen as more animalian (the chimp, the elephant, the monkey brain, the “it”).
How do these dual process models of cognition fit within the framework of intelligence we have described?

### 3.2.1 Dual process models of cognition

| The sub-conscious | System 1 | the “it”, the chimp, the monkey brain, |
|-------------------|----------|---------------------------------|
| The conscious     | System 2 | the “I”, the human, the press secretary, the rider, the spirit, the soul |

One possibility is that part of the nature of System 2, the system that we align so closely with the human in the analogies, is to act as a self-model.

Even if there are no other intelligences in our environment, to be predictive about the way events will play out, we need to have a model of ourselves. A model that allows us to predict what we would do given a certain set of circumstances. A sense of self. Such a model would need to be able to imagine circumstances, explore feelings, and predict responses. It would need to be able to predict our own response to what we might experience in the future.

Each of the dual process theories and analogies described above agrees that System 2 is dominated by System 1. That when we are forced to think quickly, the sub-conscious dominates. Haidt’s analogy captures this well. The rider (System 2) thinks it’s in charge, and even plans the elephant’s (System 1) day. But at any given moment the elephant may choose to wander off in to the forest and there’s little the rider can do about it.

The idea of the monkey brain with the press secretary emphasizes the importance of the nature of communication between entities. Selfish motives may not be best shared with a wider group as they will lead to a lack of trust. Whatever underlying motivations may be arising in System 1, System 2 as press secretary is likely to present them in the best light possible. In any environment of different intelligences, there will be drives towards conflict and drives towards co-operation. Some potential for dishonesty in our self model is therefore unsurprising, but equally it would be unsurprising if other intelligences were well tuned for detecting such dishonesty.

### 3.3 Sense of Self

The tendency to associate System 2 with the human, with “I”, reflects the fact that it embodies our preferred view of ourselves. If System 2 gives us our sense of self, then it’s natural that it gives us also a sense of freedom. Our conscious mind clearly has a strong role in planning. Imagine the converse, imagine our conscious selves had a sense of pre-determinism. This would be prohibitive for planning. “What if?” questions would be prohibited by our underlying knowledge that our actions were predetermined given the circumstances. Whether or not they are, it remains important for our System 2 to believe they are not. This sense of control is an important part of the “User Illusion” [13]. Just as the rider of the elephant has to believe he controls the elephant if he is to plan a tomorrow’s work in the forest.

Note that any self-model necessarily has to be a approximation to our true nature, it cannot capture our entire complexity because it sits within us. To be 100% predictive of ourselves, our self-models need to fully replicate ourself, i.e. to distort Laplace’s language our self-models must contain “all the forces by which we are animated”. But if we place the model inside the system, then the model must contain itself. So in the manner of the snake trying to swallow its own tail, it actually has to predict its own behaviour, as well as the behaviour of our wider selves. So it is a computational Russian doll, to sit within us it must be smaller than us, so it cannot represent all of us. This recursive effect means that necessarily, our sense of self must be an approximation of what we are.

One symptom of that requirement may be the sense of separation between our minds and our bodies that characterizes Cartesian dualism. It seems necessary for our self-model to believe it is in control[This

---

9To see why, just imagine the converse. Imagine that the self-model was aware that we are subservient to circumstance. In this case when thinking ahead, when asked to suggest how events might pan out, the self model would always answer with “I don’t know, it would depend on the precise circumstance”, which might be true, but it’s not particularly useful. It would seem more useful for the self-model to believe it would actually be in control, so that it could rise above circumstance. That being the case our self-model can always give an answer. But by the same token it implies our self-model would have an over-inflated sense
necessity and that could lead to the disconnectedness that dualism focuses on. The same disconnection that causes people to think of their spirit as separate from their flesh [13].

Many of the characteristics of our conscious selves may emerge as a consequence of our high embodiment factor. If I’m driving and following another car, I can judge the mental state of the driver by the way they are driving. Are they hesitant because they are looking to park or are they hesitant because they are a young driver? Are they angry or are they late for work? I can form these inferences because I have an understanding of myself, and I can project that understanding onto others. We have a shared base of experience, and even with minimal communication (the flashing of lights, the hoot of a horn) I can imagine the other driver’s mental state. I can do this for me and, and I can do this for others.

In our society there is a tension between our individual goals, and shared goals. So this level of understanding of each other also comes with pitfalls. We withhold information, to better protect ourselves, if we think there is dissonance between motivations or goals across the group. We share more information if there is a relationship of trust between group members.

In summary, we have argued that the nature of our intelligence is largely dictated by what we’ve defined as the embodiment factor, the ratio of our ability to process information to our ability to communicate information. With humans (and other animals) the major constraint is the very limited ability to pass information between intelligences. We’ve suggested that our complex cognitive processes are a direct result of the need we have to make best use of the limited bandwidth we have for communication.

4 The Computer

The complexity of our communication, and the limited channels with which we express ourselves, is arguably the driver of much that is beautiful in our society. Much that we admire in each other, in our culture, and in our own sense of individual identity and freedom. It could even be argued that consciousness itself is merely arising because of our inability to directly communicate our mental state. The many plays we each direct in our minds would not need actors or other imaginings if we could simply synchronize their scenes with the touch of a button.

Our computers are in a very different position. They can communicate almost as rapidly as they compute. If the human brain is an F1 car with bicycle wheels, then the more lowly machine intelligence we have developed has far less cognitive power, but it can deploy it far more efficiently. To use our race car analogy, it is like a well balanced go-kart. Small engine, but sensible tyres. Machines can deploy their intelligence through rapid inter-communication. This efficiency means that in many tasks they are already overtaking us, and they are deploying their intelligence in ways which we find difficult to understand because they are so different architecturally. They don’t conform to our evolved understanding of how other intelligences should behave. What would we think if we replaced one of the actors in Beau Willimon’s hot drink scene with a computer. What would we think if it was our a digital assistant, rather than our partner, that made us a coffee in that moment? Would that be spooky or comforting? The power of the scene is centred around shared experience, experiences that we, arguably, can’t share with a computer. If the entire scene was between two computers. Then it wouldn’t make sense at all, because if one computer was to form such an emotional attachment to another, it could simply download itself onto the other and have a permanent companion.

4.1 Modern Computer Algorithms

In comparison to our own intelligence, the machine intelligence of today is data inefficient: it requires vast quantities of data to recreate what humans can do with very little data. Current state of the art visual systems are trained on many millions of images [14], the AlphaGo [15] program which beat Lee Seedol had played over 30 million games of Go before facing him (more than any human could play in a lifetime). But although our machine intelligences are very inefficient, they have become effective because they have high bandwidth communication and now they have access to all the data they need. The machine intelligence technology of today is entirely dependent on our computers’ ability to access our data.

Our modern learning algorithms are ignorant of context and are mainly driven by fairly simple goals like guessing whether or not you’ll click on a particular advert [16]. Or whether or not your face is in a particular photo [17]. Having understood their simple goal, these cognitive go-karts can monotonously complete laps of their information processing circuits extremely efficiently. In contrast, humans, with our over powered, locked-in intelligence, seem to aimlessly pirouette and collide like a rugby club production of The Nutcracker.
Algorithms are operating according to a different set of rules. So how do we constrain the operations of the machines? How do we regulate their interaction with data so that they do not transgress our freedoms?

In the real world we develop relationships of trust with our friends and family that enable us to share our innermost thoughts and failings. Whether its our health, our political beliefs or our sexual desires. We are protected by our limited bandwidth of communication, our bonds of trust, our tendency to forget things and the finite nature of our lives. By retaining something of our self to our self, we retain freedom of action because there are motivations which are known only to us.

Modern algorithms simply watch our decision making. They monitor our inputs, and they monitor our actions. They use mathematical models to reconstruct the responses we'll make given the known inputs. They emulate our intelligence, not through a deep understanding of motivation, but through large scale data acquisition and clever reconstruction. It turns out, that if you have large storage and a lot of data, then you don’t need the internal actor-driven model of human behaviour, because with sufficient data we also turn out to be very predictable [18]. Machine predictions about humans are made in a fundamentally different way from those that humans make. They are purely data driven, and since our data reflects our prejudices, so do the machine’s predictions. Machine predictions are also context-constrained, they reconstruct on the basis of the information they’re given. That won’t include the entire basis of our decision making, so while they can store more data, they are fixed in terms of what they take into account. This makes them brittle: they will fail when placed in unfamiliar circumstance.

The algorithms we develop don’t have a sentient nature, if we were to characterise them according to the dual process model of cognition, they are data driven, input-output. They see then do. In Kahneman’s parlance, they think fast. If they see data that is biased against a particular race, they are racist. They don’t incorporate contextual regularizers like we do. They also operate below our cognitive radar. We occasionally see the outcome of their decision, with an advert placed or a loan application denied, but we cannot relate to the computer in the way that we relate to each other.

4.2 System Zero

The algorithms we create can also exploit our own cognitive biases. Many of them are designed to change our behaviour. To make us buy something or read something. They improve their effectiveness at achieving this by running large scale tests across populations containing millions. They explore what is most effective at encouraging us to click an ad, to make a friend, or to read an article. They adapt our digital environments to encourage more of the behaviour they prefer.

In recent electoral cycles there has been a lot of concern about Fake News. But arguably the real story is how did we develop social communities where such Fake News can pass unquestioned, and even be celebrated?

Such communities develop because many of us, at a superficial level, seem to prefer to interact with people who reinforce our own prejudices. Even if, at a deeper level, we each want to overcome prejudice and improve ourselves. When we are thinking fast, we choose friends and read material that validates us.

Once we are in such communities we are happy to read and share news articles that further confirm those prejudices, regardless of underlying truth. Our cognitive regularizers are overwhelmed by the resulting syrupy harmony in our social set.

Note that there was no grand plan to bring this unhappy circumstance about. It is a consequence of machine intelligence fulfilling our superfluid desires. It sees that we drink from the syrup, so it feeds us more. This is non-sentient, reactive intelligence. It is even more disturbing because of its interconnectedness. I call it System Zero because relating it to a dual process model, it sits underneath the elephant, and therefore under the rider. It interacts with our subconscious and is not sufficiently embodied to be represented as an actor in our mental play of life. But nevertheless, it is there, effecting all our evolving story lines, and so pervasive that it is accommodating very many of our personal elephants at the same time. It is the proverbial turtle on which our world of elephants resides. And on the back of that turtle each of our elephants feels an artifice of freedom, oblivious to the movements beneath. So the rider continues to feel in control despite the fundamental change of direction. Ironically, all the time we are actually steering the turtle, it feeds on our unregulated subconscious desires.

Our own freedom of action fundamentally depends on the high embodiment factor of our intelligence. System Zero now acts as a new high bandwidth channel to limit that freedom of action. And it does so while operating beyond our cognitive horizons.
5 Next Steps

Machine intelligence may be undermining our cognitive landscape driving us into what R. Scott Bakker has referred to as a crash space\textsuperscript{[10]} a cognitive environment which has moved beyond that we are mentally equipped to deal with.

There are, of course, many advantages to an information society. But to fully reap their rewards we need to be more cognisant of the perils. With that motivation, this paper has presented a fairly dystopian perspective of contemporary machine intelligence. There are already, and there will continue to be, many benefits for society from machine learning. As a researcher in machine learning, I have long been, and will continue to be, inspired by those benefits. But those benefits will not be realised if we do not overcome the pitfalls.

One objective of this article is to debunk certain myths about machine intelligence that can dominate the debate. In particular, there is a great fear of ‘sentience’ in our artificial intelligence systems. There is concern for the death of the species through the creation of a sentient entity with goals that are not aligned to ours [20]. But sentience is not required for this to be brought about. System Zero is already aligned with our goals. It’s just that it’s aligned with our subconscious goals. And because System Zero is not sentient it cannot regularize with the necessary context. Therein lies the problem. It is fully aligned with what we want, but not what we aspire to. It gives us friends that agree with us and fake news that confirms our prejudice. System Zero short-circuits the complex connections we have evolved between our selves, it reflects the needs of flesh and body, and it undermines our spirit and our soul.

These challenges are addressable. Three particular actions stand out.

1. Encourage a wider societal understanding of how closely our privacy is interconnected with our personal freedom. When we share our data with non-sentient intelligenes, they reflect back at us a caricature of ourselves that is driven by that aspect that we have variously characterised as “it”, “the elephant”, “the chimp”, the “monkey brain”, “the body” or “the flesh”.

2. Develop a much better understanding of our own cognitive biases and characterise our own intelligence better. This would allow us to develop machine intelligences that are sensitive to our foibles, rather than exploitative of them. System Zero emerges when we develop intelligences that are incentivised by short term reward, the most efficient way of achieving such reward is to exploit our cognitive biases for greater profit. This exploitation also occurs without understanding, because machines can unpick our cognitive biases through large scale experiment, but yet they are unable to relate their discoveries to us. They do this relentlessly driven by our data and society’s profit motive. By better understanding our conscious selves we can better reflect our own sensitivities in the machine.

3. Develop a sentient aspect to our machine intelligences which allows them to explain actions and justify decision making. Force them to do so in terms which humans understand. This will bring these intelligences back into our cognitive ecosystem. We should make machine intelligence self aware, not so it rises against us, but so that it works with us. Self awareness is the mechanism for high level communication with humans. It is required so that the machines can also be represented as actors within our mental plays.

As so often when faced with new challenges, the right reaction is not to generate fear of the unknown, but understanding of the known and research into the unknown. Innovation continues to be the watchword, but innovation in an enlightened society. Innovation in a society that understands the issues and the consequences. There is a need for more research and more education. We require better understanding of ourselves and our society. Our society requires better understanding of machine intelligence. Since such understanding has always been at the core of the human condition, the challenges of machine intelligence should be seen as an opportunity. We have crossed the Rubicon, now we must march on Rome.

6 Acknowledgements

The author thanks Mariarosaria Taddeo, Tom Stafford and R. Scott Bakker for comments on an earlier draft and Beau Willimon for permission to use the hot drink story.

\textsuperscript{10}Roughly speaking, a crash space is an environment where our internal models, our psyche, is no longer fit for purpose. In this environment Bakker speculates that human behaviour would degrade very rapidly. In the language of this paper, the failure of our internal predictive models would lead us to a situation where “all cognitive bets are off”. Bakker’s paper on Crash Space is driven by the notion of wiring the brain, physical implants within the brain that make a direct change on way in which we receive information. System Zero differs slightly in that it is not a conscious intervention, but just systemic side effect of large scale interaction with the machine.
Bibliography

[1] P. S. Laplace, *Essai philosophique sur les probabilités*, 2nd ed. Paris: Courcier, 1814.
[2] C. Reed and N. I. Durlach, “Note on information transfer rates in human communication,” *Presence Teleoperators & Virtual Environments*, vol. 7, no. 5, pp. 509–518, 1998.
[3] R. Ananthanarayanan, S. K. Esser, H. D. Simon, and D. S. Modha, “The cat is out of the bag: Cortical simulations with $10^9$ neurons, $10^{13}$ synapses,” in *Proceedings of the conference on high performance computing networking, storage and analysis - sc ’09*, 2009.
[4] P. Hagmann, “From diffusion MRI to brain connectomics,” PhD thesis.
[5] O. Sporns, G. Tononi, and R. Köttter, “The human connectome: A structural description of the human brain,” *PLOS Computational Biology*, vol. 1, no. 4, Sep. 2005.
[6] J. B. Tenenbaum, C. Kemp, T. L. Griffiths, and N. D. Goodman, “How to grow a mind: Statistics, structure, and abstraction,” *Science*, vol. 331, no. 6022, pp. 1279–1285, 2011.
[7] K. Frankish and J. Evans, “The duality of mind: An historical perspective,” in *In two minds: Dual processes and beyond*, J. Evans and K. Frankish, Eds. 2009, pp. 1–29.
[8] S. Freud, *Das ich und das es*. Internationaler Psychoanalytischer Verlag, 1923.
[9] D. Kahneman, *Thinking fast and slow*. 2011.
[10] J. Haidt, *The happiness hypothesis*. 2006.
[11] S. Peters, *The chimp paradox*. 2012.
[12] C. F. Camerer, G. Loewenstein, and D. Prelec, “Neuroeconomics: Why economics needs brains,” *Scandinavian Journal of Economics*, vol. 106, no. 3, pp. 555–579, 2004.
[13] D. Dennett, “Consciousness explained,” 1991.
[14] O. Russakovsky et al., “ImageNet Large Scale Visual Recognition Challenge,” *International Journal of Computer Vision (IJCV)*, vol. 115, no. 3, pp. 211–252, 2015.
[15] D. Silver et al., “Mastering the game of Go with deep neural networks and tree search,” *Nature*, vol. 529, no. 7587, pp. 484–489, 2016–1AD.
[16] H. B. McMahan et al., “Ad click prediction: A view from the trenches,” in *Proceedings of the 19th acm sigkdd international conference on knowledge discovery and data mining (kdd)*, 2013.
[17] Y. Taigman, M. Yang, M. Ranzato, and L. Wolf, “DeepFace: Closing the gap to human-level performance in face verification,” in *2014 ieee conference on computer vision and pattern recognition*, 2014, pp. 1701–1708.
[18] M. Kosinski, D. Stillwell, and T. Graepel, “Private traits and attributes are predictable from digital records of human behavior,” *Proceedings of the National Academy of Sciences*, vol. 110, no. 15, pp. 5802–5805, 2013.
[19] R. S. Bakker, “Crash space,” *Midwest Studies in Philosophy*, vol. 39, pp. 186–204, 2015.
[20] N. Bostrom, *Superintelligence: Paths, dangers, strategies*, 1st ed. Oxford, UK: Oxford University Press, 2014.