Constraints on 'Message Construction' for Communication with Extra-Terrestrial Intelligences

Dr William H Edmondson, School of Computer Science,
University of Birmingham, Edgbaston, Birmingham B15 2TT, UK.
w.h.edmondson@cs.bham.ac.uk

Introduction

When thinking about CETI it is necessary to make some assumptions – clearly the nature of these can range from the minimalist to the fanciful. The motivation for one's assumptions needs also to be made explicit. Here my motivation is to explore what is *necessary* in any communication scenario involving ETIs, and also what constraints must be put on conceptions of possible 'messages'. The goal is not to limit the fanciful end of the spectrum of assumptions, merely to limit the whole range to the domain of plausibility, a domain which includes aspects of altruism and aesthetics. It is also argued that it is necessary to consider what is possible for humans to construct as initial messages – if we do not then we are poorly placed to find and decode incoming initial messages.

It is *not* assumed that systems of explanation or of knowing are the same as ours, merely that what is explained or known must be about the same universe – thus it can be supposed that the electro-magnetic spectrum is 'known' in a way which matches our knowledge, and some basic concepts of mathematics/information theory must be generally known (the directions and emphases taken by basic research in physics/chemistry/mathematics arguably must eventually cover the same ground, although not necessarily with the same historical or intellectual routes). It does not seem necessary to assume much more sophistication than this in order to construct a scenario for behaviour which can be communicated reciprocally by intelligences to establish the bases for more comprehensive communicative behaviour.

Assumptions

Physics

One core assumption made is that the 'physics' of the universe is knowable locally. It is further assumed that the sensory apparatus of beings in the universe must deal with the dimensionality of existence, physical/chemical stimuli and the electro-magnetic spectrum. Some form of

taste/smell, touch, and 'auditory' perception must all be possible (even if the 'biophysics' is radically different from ours, and ETs are, say, primarily 'aquatic'). Likewise sensitivity to the electro-magnetic spectrum must be presumed, both in terms of general sensors (we think of these as heat sensors) and two-dimensional arrays of sensors (imaging sensors for converting three dimensional distal stimuli into two dimensional proximal stimuli). The claim, in short, is that the sensory biophysics of any ETI is functionally equivalent to ours, and that this is plausible because the physics of the universe is uniform. Note – it is not claimed that the visual system of an ETI would map onto ours in terms, say, of spectral sensitivities of retinal cells, or flicker/fusion performance, or acuity, or etc., and likewise, *mutatis mutandis,* for audition, touch, taste/smell. All this, in my view, can be assumed uncontroversially.

The consequences of even these rather simple assumptions, for consideration of CETI possibilities, are quite considerable. In particular, it is arguable that what we call audition will not be shared in any interesting sense by any ETI. The speed of sound on any planet will be very dependent on locally determined factors (atmospheric density, composition, temperature). The range of frequencies to which an organism is sensitive is not predictable on physical grounds. For example, on Earth some organisms are sensitive to very low acoustic frequencies and some to very high frequencies. The range is considerable. In vision, by contrast, the range is smaller, and at the lower end (the 'red' end) the range extends into the infra-red for which organisms have developed heat sensors not arranged in two dimensional arrays. Some organisms are sensitive to the polarization of the light, and some to frequencies we call ultra-violet. In the visible spectrum the effect of the environment/atmosphere is less pronounced than for sound (to be sure, aquatic light transmission is grossly attenuated, but it works with a spectral range which is much the same as for air). Note, additionally, that the physics of the world determines what is heat and what is light (in terms of, say, the vibrational motion of atoms in a solid).

If these conjectures are plausible, and I believe they are, then our first constraint on possible messages is simple: don't think of 'sound worlds' or music or speech as the domains, vehicles, or contents of ETI messages. Regardless of semiotic concerns (see below) assumptions about the accessibility of acoustic messaging must remain questionable. Furthermore there will be intended and unintended aspects of performance which elaborate the difficulties of using sound. In my view avoidance of the sound world need not be controversial.

Cognition

I assume that some general cognitive principles have universal applicability, and also that some aspects of cognitive functioning are necessary, and thus universal, corollaries of intelligent behaviour: intentionality, distributed cognition, contextualization. This position is much more controversial.

General cognitive principles, as I have developed them (Edmondson 2000, cf. Chomsky 1980), are pan-specific principles expressive of a general notion of the functionality of the brain (any brain – note that we understand 'how the heart works' and 'what the heart is for' in a pan-specific way). The central idea is simply that the brain provides the means whereby the temporal dimension of experience and behaviour is mapped into and out of cognitive structures (memories, plans, beliefs,…) which may be about such temporal structures without being temporal in the same sense. My notion of boiling an egg does not itself unwind, or read out, or bubble along, for 4 minutes – it is about the duration without having duration (it endures, which is different). Likewise, my notion of the structure of a sentence, with subject and predicate arranged as in English, does not itself have that same sequential structure – it is about that structure. The sequentiality is required psychophysically for penetration of the corporeal boundary – atemporal cognitive entities (thoughts, plans, intentions, language….) must be sequenced to be externalised; perception requires 'desequencing' in order to internalise (the visual system of organisms imposes sequentiality through saccades and/or head movements). I refer to this psychophysical requirement as the 'sequential imperative' and it is at the core of any functional specification of any brain.

The significance of general cognitive principles for communicating with ETIs is simply that the sequential imperative will be universal and that behaviours dependent on culturally determined serial organization of behaviour will be so arbitrary as to be incomprehensible – there will be no basis for contextualization. Contrastingly, where sequentialization is determined physically we can be sure that this is recognizable and its lack of arbitrariness is readable as such. This might prove useful in the design of messages.

Symbols

One aspect of the above discussion is of immediate importance; it is that sequence is often semiotically free (i.e. when not constrained by the natural sequentiality of physical events or deployment of physiology) and thus available to carry meaning as desired. The arbitrariness of

meaning associated with physical behaviour is problematic for CETI because the behaviour itself, although it might evidenced in some way, is simply not informative. Human use of symbol systems requires both cultural and situational contextualization – we have to be able to consider the symbol usage alongside both other behaviour, the situation in which these behaviours take place, and the circumstances of both learning and cultural transmission. The background knowledge and situational context are not, however, part of the symbol system, and are not available to an ETI (and as a consequence the conditions for ETI to learn a human language are not in place). This is why symbol systems and languages look implausible as components or goals in any CETI attempt. The fact that on Earth we can currently find around 7000 spoken and signed languages suggests that the arbitrariness is not a trivial obstacle – especially when we recognise why that arbitrariness exists. Hockett's (1965) work on design features shows us that recognition of arbitrariness is not controversial – linking that to the sequential imperative perhaps is controversial. Note, incidentally, that although Hockett's account of arbitrariness is expressed in terms of double articulation – arbitrary meaningless elements (from a set of such) combined into arbitrary groups which are meaningful – it is entirely plausible that larger groups still (groups of groups) can be assessed both in terms of arbitrariness and also in terms of other semiotic qualities, like aesthetic value (ugly and elegant sentences, for example, both syntactic but with different aesthetic 'value'). These values would not be available to an ETI, however we can suppose an ETI to be aware of the general principles concerned.

In order to appraise the (im)possibility of establishing linguistic communication with ETIs it is helpful to consider some examples from human existence which pose problems for us today. One example is 'rock art', patterns or shapes cut into rock many thousands of years ago. These can be found in many countries – one example shown here is from near Sheffield, in England. [Image from :http://www.shef.ac.uk/~geap/rart.htm]

Our problem today is that we cannot really say what these patterns mean, why they were cut into rocks, by whom, and so forth. To all intents and purposes these patterns might have been made by aliens (and one need only think of Velikovsky or von Daniken to see where that line of thinking can end up). The real difficulty, for scientists, is that in reality we will never be able to say what the patterns mean, unless we find a readable exegesis of them produced at the time they were made.

More intriguingly, and arguable more obviously related to attempts at CETI, there is the problem of the Voynich manuscript. This lengthy document, on vellum and probably dating from the 15th/16th Century, is undeciphered despite many efforts. What is not clear is whether or not the 'writing' is in fact linguistic – there are no convincing reasons to suppose the document is not a hoax of some sort. [Examples here from two Voynich sites on the web:
http://www.geocities.com/Athens/Delphi/8389/voygal1.htm
http://www.crystalinks.com/voynich.html]

The example of the Voynich manuscript raises a general concern about CETI – how will one know that one has received a message which is a communicative artefact? Any sort of 'linguistic' or serial organization of symbols presents a major problem for interpretation because of the arbitrariness and semiotic opacity – these may be so pervasive that the artefactuality is obscured, but even where there are good reasons to suppose a communicative effort is being made it may actually be impossible to uncover meanings. Clearly this concern applies to the raw signals as well, but recovery of a signal artefact looks less problematic than knowing what to do with it!

In my view the above considerations lead to a second constraint – CETI cannot be linguistic or based on any sort of symbol system. The requirements for successful decipherment cannot be established – there is no shared experience, location, or behaviour, and there is no parallel text.

Intentions

In human discourse an essential presumption is that intentionality exists and that it is understood – communication fails if the intentions are not clear. It seems to me much more plausible to suppose that communicative intent can be presumed universally to be required of a being wishing to communicate to another. The importance of situated behaviour, and of the need for assessment of the communication situation in relation to intention, seem compelling – it is what we humans must do to recover intention and it seems unlikely that avoidance of situation awareness will be possible in any communication situation. It therefore makes sense, in my view, to assume that if an ETI is interested in communication with other ETIs it will endeavour to behave with some communicative intentions, paying explicit attention to the peculiarities of the communication situation. ETIs will be concerned to be found, to be identified/located, to provide/specify the means for a return communication, to be understood at some level, to commence a dialogue

rather than merely post a notice, to display situation awareness, and etc. This will be illustrated below.

Distributed cognition

It is commonly supposed that cognitive activity is isolated and 'within the head'. The core concept of distributed cognition (due to Hutchins (1996)) is that brains are not isolated cognizers working on processing concepts in relation to sensory data – rather it is better to think of cognition as spread out in space and time and amongst other cognizers.

Cognition is distributed over *space* – humans are good at doing this; we leave 'PostIt' notes all over our offices, and we use diaries and address books as cognitive extensions. In these and other ways we distribute our cognition into space. Cognition is distributed over *people.* In plant control rooms, or spread out doing different tasks in the operation of complex equipment such as a naval vessel, or perhaps just as two mechanics fixing a car…, humans rely on situation awareness in order to appreciate their individual role in the larger endeavour. Situation awareness relates both to tasks and other cognizers, and is required in individuals for successful problem solving, as well as in groups. Cognition is distributed over *time* – both within individuals (this is not part of Hutchins' account) and across individuals. Solving a problem, or developing a specific tool, requires successive cognizers to contribute in a way which ensures that other, later, participants recognize the cognitive activity and engage in it at a 'temporal distance'.

It is of interest that knowing about distributed cognition and situation awareness provides explanatory insight into sensations of 'mind-reading'. Engaging in teamwork can sometimes create the sensation that 'one knows how the other person is thinking', and indeed this is in a real sense true – both are engaged with the same task, and have awareness of the situation, and perhaps some specific training…. When using a tool one can have the sense of knowing how the originator thought of it, and this is again because one is working with essentially the same task and situation. Improvements in tool design reflect an ongoing engagement with the task and the situation, and also with those who contrived the earlier solution.

I would like to suggest here that cognition can be distributed over species too. Where the physics of the universe determines certain properties of tools and artefacts on our planet then surely our deliberations about such items can in appropriate situations be shared by other species on other planets. The deployment of levers would be a clear example, as would the design of wheels for

particular terrains. Although we take these as commonplace on our planet, our engagement with the situation in distributed cognition surfaces as soon as we need a special version (wheels with soft tyres, or for robot vehicles crawling over Mars; levers with special end shapes to prevent slippage, as in crow-bars). We should in a real sense be able to understand or read the shapes of such items in the world of an ETI. In order to potentiate understanding of any communication to/from an ETI we should envisage exploiting the sense of sharing which comes with distributed cognition. This is not a hard constraint, but goes beyond mere possibility.

Message Design

Content – I

Our discussion so far has specifically considered ruling out symbol systems, language, and systems based on sounds or music. The significance of the sequential imperative is that sequentially organized material in general is not suitable. Additionally, a focus on concepts shared through problem solving (levers, wheels, etc.) exploits what we understand from distributed cognition, and indeed similar concerns oblige us to think carefully about the intentions of any ETI communicating with us. We are concerned here with what we would construct as a message in order better to understand anything we may detect being sent to us. (Later we will consider some aspects of the layering considered necessary by many at the workshop, myself included.)

My interpretation of all this is that we should be concerned to transmit/receive images, somehow, and these images should contain task or conceptual material which does not *require* sequential interpretation (but which could be informative about sequencing). Furthermore, the intentionality is plausibly constrained to make the 'message' more substantial than: 'we are broadcasting some beacon-like signal to everyone, wherever you may be, so that you will merely know that we exist'. Rather, we should expect something more like: 'we, who look like this, are here, which looks like this, and we know about this sort of thing which we think is the minimum you should be able to recognize and build on if we are to establish a dialogue of some sort'. In other words, we should expect intelligences to think 'altruistically' about the communication situation, altruistically in the sense of putting themselves in the situation of the intelligences who receive the messages. Altruism is based upon situation awareness, ultimately.

Before discussing some specific ideas for the channel/transmission system which could be used let me say something about message content. If we were to be sending out a message to ETIs I would, despite the apparent waste of signal capacity, transmit a full colour image of a group of humans – or rather several images, arranged in a grid rather like one of those postcards which offers several different images from the city or region you are visiting. Call this component of the transmission 'postcard earth'; we might assume an ETI is sending out such postcard images. Simultaneously with the image I would interleave in the signal a monochrome image of a diagram - or several diagrams – which do not require sequential interpretation unless that is self-evident. For example, an illustration of Pythagoras: 'the square on the hypotenuse equals the sum of the squares on the other two sides', with some algebraic formulation as the basis for introducing a symbol system which is not sequentially constrained irrecoverably, could provide the basis for a 'parallel text' type of communication where the diagram (the known component) provides the basis for deciphering the unknown notation. I would include a diagram of the energy spectrum of the sun's radiation, with points marked to indicate our colour sensitivity (and to provide the basis for colour rendering of the coloured images). Perhaps diagrams could be included showing the interrelatedness of species in evolutionary time, the solar system and our location in it, and so forth. The options are many and challenging, but the approach to be taken seems clear enough.

Channel

The transmission itself can be organized to indicate intentionality. For example, instead of just a general omni-directional broadcast, we should direct our transmission with recoverable intent. There are potential beacons in the galaxy called pulsars, and we should refer ourselves to these. We can transmit back towards such pulsars, with signals pulsed at the same rate. Any ETI roughly between us and the pulsar (the roughness depends on the properties of the antennae involved) will need to be looking specifically away from pulsars for signals at the specific rates of those pulsars. This is, at first blush, a basic and unambiguous way to use pulsars with the intention of being found. We should look in the directions specified, for the signals specified, knowing that doing so reflects recognition of the intent of an ETI to communicate using the same procedure. In terms of distributed cognition and shared intent the plan makes sense as an expression of a shared solution to a shared problem, where both parties know they share the problem and the solution.

The radio frequency of choice might well be the ubiquitous 'hydrogen frequency' reflecting both knowledge of the distribution of the elements in the universe, and technical ease of generation and transmission. The pulse rates are defined by the pulsars used for reference, but it 'makes sense' in terms of effort to use more channels than just the single pulse train at 1.42Ghz. Different choices are possible, and the technical insights of signal engineers would need to be exploited (in the sense of distributed cognizers solving the same problem across the galaxy). We should assume information theoretical knowledge (as much as maths and physics) and perhaps go for some combinations of channels and time multiplexing.

Content – II

The transmissions themselves, as a sequence of pulses or patterns thereof, can be used to encode location in the galaxy in relation to pulsar beacons. Pulsars have different pulse rates, so encoding relative pulse rates for pulsars in orthogonal formation in relation to the transmitter would permit a receiver to calculate where the transmitter is (orthogonality can be presumed to be understood). The coding schemes would require care, but the principle driving such an approach, and thus assumable in the intelligence who detects the signals, is that the transmitting intelligence intends to be located. We thus get close to covering all the points mentioned earlier – the signal itself, and the properties of the channel in terms of pulse trains, and the content as images, amount to: 'we, who look like this, are here which looks like this, and we have a vision system which has the these sensitivities, and we write Pythagoras this way, and ….', which is a plausible way to start a dialogue.

Layering

During the course of the workshop the issue of layering was mentioned several times – the need is for messages to have layers of structure and motivation. This is unsurprising (cf. Hockett) but it raises a possibility not specifically addressed at the workshop, one which has been part of my thinking on the layered nature of message construction. The layers need to be mutually reinforcing in relation to interpretations and to explicitness of artefactuality. So, for example, the transmission of pulses might be organized in 16 bit bytes with a 17th bit as a spacer. This confirms the byte length (which might otherwise have to be derived statistically) and confirms artefactuality. The transmission of pulsar beacon data in the byte sequences (this can be done as ratios – see http://www.cs.bham.ac.uk/~whe/CETI.html) can be matched with diagrams showing location with reference to pulsars (so successful recovery of images with diagrams could provide an alternative way of recovering the information). The arrangement of the raster scanning of

images can be confirmed when recognizable images come up, such as the Pythagorean triangle. This latter would also permit the scale to be calibrated. And so on and so forth – the layers being at least: pulses, pulses in groups, groups of groups of pulses (all relating to a uni-dimensional expression of data), long strings of groups of pulses, perhaps arranged in simultaneous sequences exploiting frequencies related to the hydrogen frequency, coding for image data (2D), within which 3D information can be conveyed, and all cross-coupled to provide redundancy, and thus confirmation of content for the recipient ETI.

Altruism, Art and Science.

The approach outlined in this paper reflects some core concepts. Knowledge of cognitive science enables us to recognize situation awareness as the basis for altruism, which means at base no more than thinking of others and their situation. CETI is not possible without such awareness, and explicit exploitation of that awareness. Altruism is not to be encoded in any message, it is the frame of mind which makes communication possible at all and is thus expressed in whatever system/message is deployed. Failure to do this will cause the enterprise to fail.

We can also note, in passing, that the approach taken here is at odds with more conventional message models of communication (cf. Hauser 1997), and that therefore the sense of controversiality does not arise solely from our consideration of extra-terrestrials. Even regarding terrestrials the argumentation above is not uncontentious (see also Akmajian et al 1984).

Cultural relativity ensures that symbols systems can never be the option of choice for initial contacts – general principles reveal that the essential arbitrariness of such systems makes 'decoding' impossible because contextualization is impossible. However, note that an array of images in 'postcard earth' implies choice from an infinite set – so the choice made must express value judgements and this fact will be known to both parties. One must assume both aesthetics and cultural relativity would be involved in the choice and arrangement of images, as well as less arbitrary factors, and that knowing this we might find a way to deploy situation awareness to provide a way in to recover aesthetic and cultural values. This is a challenge.

Essentially, and in summary, we should begin our thinking about CETI with the central idea that 'information is the distinction between what is and what might have been'. We should recognize that the central problem facing two intelligences trying to establish communication is that the

'might have been's depend on context. However, it is a fact that some basic properties of cognition and communication behaviour establish a much wider range of necessarily shared scientific knowledge which must be exploited if message design is to be a worthwhile activity, and message detection is to become probable. That we have not yet found any signals from ETIs may mean that we are not approaching the search in the right frame of mind.

References

Akmajian, A., Demers, R.A., & Harnish, R.M. 1984. *Linguistics: An Introduction to Language and Communication.* MIT Press.

Chomsky, N. 1980. *Rules and Representations.* Basil Blackwell.

Edmondson, W.H. 2000. General Cognitive Principles and the Structure of Behaviour. Technical report CSRP2000-13, School of Computer Science, University of Birmingham. Available at: `http://www.cs.bham.ac.uk/~whe/seqimp.pdf`

Hauser, M.D. 1997. *The Evolution of Communication.* MIT Press.

Hockett, C.F. 1965. The Problem of Universals in Language. In *Universals of Language*, edited by Joseph H. Greenberg, 2nd edition. MIT Press. See also Hockett's 1961 paper: Linguistic Elements and Their Relations, *Language* **37**, pp29-53

Hutchins, E. 1996. *Cognition in the Wild.* MIT Press.

