An Irregular Dodekahedron and a Lemon Yellow Citroën.

Ranulph Glanville

I Reflective Thinking

The academic world deals in thinking, and the outcome of thinking, that is, thought.

But that's not quite it. Academics don't just think and have thoughts, they build on them, they criticise them and they put them together. Building on, composing and criticising are all varieties of thinking. So, put simply, academics think about thinking and have thoughts about (their) thoughts. They reflect, and they reflect on their reflections. This sort of thing—when we do something and then do it again, potentially ad infinitum—is called recursive, and academics are involved in an essentially recursive activity.

Almost everything that we research, which involves us doing and thinking about what we do and think, is, at heart, recursive.

Yet, in the academic world, we have tried, until recently, to avoid this recursivity. Indeed, we have tried to outlaw it by demanding, for example, depersonalised objectivity and fixity.

II Observing

This is not an article about old practices in the academic world. It is about the Practice of Practice (or practising practising). But those old practices have to come in to it, and we will see both why they come in, and how we can deal with the problems associated with them (why the academic world has tried to avoid them) by proposing an alternative way of looking at them. It is this alternative that the RMIT University masters and doctoral programmes so successfully embody.

When we study some system (I should properly say what we will come to call a system), we observe it. What we are doing is making a collection of what we will call observations, which we take to be of this system. Our undertaking is to make observations (which we come to believe are of what we come to call the system!).

So, when we study how we observe (for that is what we were doing), we are actually making observations of us making observations. Thus, carrying out our studies we are observing (ourselves) observing.

We believe these studies tell us about the systems (objects, maybe processes) we are studying: but what they tell us more about is ourselves, how we observe, what we do when we observe, the criteria which we use to set up observations, our value systems and judgements etc..

The Magician Heinz von Foerster gives us this example (von Foerster 1972). Consider what it means when we observe some thing is "indecent." We learn precious little about the thing, but we learn an enormous amount about ourselves! Even over the few years that we have lived, what is counted as indecent has changed beyond recognition. Could, then, indecency be a property of what we observe? That would be a bit difficult. Better think of it as a quality we attribute through and in our observing.

This understanding (qualities seen as attributes rather than properties) is not new. There has long been an argument about qualities: whether they are, to use an optical metaphor, projected into our sight from the object or projected by the eye onto the object—just as there has been an argument about whether we see through light entering our eye, or by means of something projected from our eyes. What is important in this is not that one side seems to be winning at the moment, but that there are two sides—and a debate

III Recursion.

Nor is the study of recursion new. The great mathematician David Hilbert in 1905 attempted to demonstrate that mathematics was mathematical, that is, it didn't need anything else to justify its existence, that is, which it had to refer to. If you think for a moment about how we use mathematics, the significance of being able to work in this belief becomes apparent. We depend on mathematics; on its reliability, claiming it gives us truths. If it relies on something else, our faith in mathematics (a belief which amongst some mathematicians tends to the religious) is not so well-founded and the foundations of much of our knowledge and view of the world are undermined.[1]

It was to deal with such considerations that Hilbert set up the "metamathematics programme." Metamathematics is the mathematical study of mathematics as a subject—of the conditions surrounding mathematics. Hilbert wanted, desperately, to show that mathematics was mathematical—that it didn't depend on or have to refer to any other subject (to do so would only be to transfer the problem). He wanted a mathematics of mathematics. There is a long and interesting story to be told about his attempts and the eventual outcome, but that is for another occasion. The point is that almost 100 years ago the formal study of mathematics, done mathematically, was officially instituted: the mathematics of mathematics. And the mathematics of mathematics is, of course, recursive.[2]

In our world as designers this recursive, reflective process is deeply set. As designers, some of us make educations for designers: we are attempting to design designers (or, rather, to help them design themselves). When we look at practice and try to improve that practice by practising on it, we are involved in the practice of practice: for we design, consider our design and improve it by designing on the basis of what we have: and when we look back, our designing was based on (an earlier instance of) our designing, which is a recursion. If we build theories, and then consider what it is to build theories, we theorise about theorising.

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1 Good introductions to Hilbert and his programme can be found in Encyclopaedia Britannica: http://www.britannica.com/eb/article?eu=41309

2 The mathematics and logic of recursion was developed by the Norwegian Thoralf Albert Skolem. Recursive function theory has become ever more significant and important. Think of the following: Adam and Eve were human: their offspring were human: the offspring of their offspring were human…we are human, where our humanity is determined by recursion to a source (Adam and Eve), but is equally determined by the "offspring of offspring." Again, Encyclopaedia Britannica is a good starting point. See article at: http://www.britannica.com/eb/article?eu=64522

IV Cybernetics of Cybernetics

There is one subject that has made a special feast of this recursive, reflective process. This is cybernetics.[3] In 1968, that remarkable anthropologist Margaret Mead (one of the founders of cybernetics in the 1940s) gave the inaugural address at the founding of the American Society for Cybernetics. This was a big, auspicious event, attended by many very distinguished people and was held under the auspices of the American Association for the Advancement of Science meeting that year. Mead's address was entitled "The Cybernetics of Cybernetics" (Mead, 1968). As she remarks in this paper, some time earlier she had asked an incredulous Society for General Systems Research if it should not consider itself as a system. Here, she suggests that the fledgling society should define itself by a cybernetic analysis of what such a society might wish to be.

But behind Mead was that same old Magician, Heinz von Foerster. It was von Foerster who gave Mead her title. He, as the moving spirit in fledging the new society, had both invited and briefed Mead. And it is to von Foerster, more than any of the others who were involved, that the development of the cybernetics of cybernetics is generally and correctly attributed.[4]

Von Foerster's inspiration was the example concerning observing that I have summarised above. Following the lead he gave Mead, he organised an elective at the University of Illinois in which cybernetic material from earlier days was collected and examined (by learners, i.e. students) using the sorts of techniques that had been developed in cybernetics. Thus, cybernetics was examined cybernetically, or, to write it out in full, cybernetic material was subjected to a critical evaluation using the techniques and insights that had been developed in and through cybernetics.

The outcome of this elective was an enormous, greatly valued (and-very-hard-to-find-even-though-recently-republished) book, "The Cybernetics of Cybernetics," originally published in 1974 (von Foerster, 1974). In this von Foerster differentiated between two orders of cybernetics. Old cybernetics, the original, was called first order and was the cybernetics of observed systems. The new cybernetics, called second order cybernetics, was the cybernetics of observing systems. The new cybernetics and second order cybernetics were synonyms for the cybernetics of cybernetics.

Since then, those at the cutting edge of cybernetic thinking have been preoccupied with the cybernetics of cybernetics: reflection, recursion and circularity—dealing with the problems that come with these notions.

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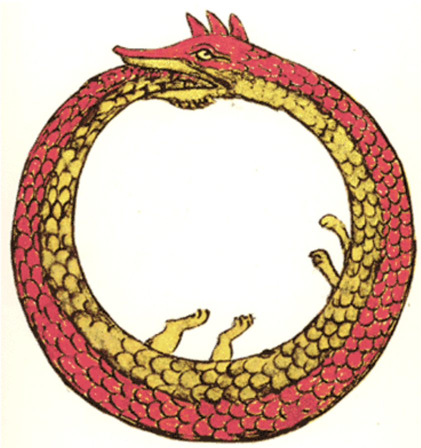
[3] For a nice, short introduction to cybernetics for architects and designers, in a way that is related to the arguments presented here, see van Schaik 2002.

[4] See the charming and short account of the basic argument in support of the development of the cybernetics of cybernetics in Foerster (1979). For a summary of wider scope see Glanville (2002).

V An Abomination

Interestingly, this concern is not all new, either. Reflexive, self-referential studies have long been considered an abomination. In earlier times, and particularly in the Middle Ages, a special fictional animal was frequently depicted to embody this evil: the Oroborus (or ouroborus). This, the snake (dragon) that eats its own tail, looks like this:[5]



Classical subjects, and the form of classical areas of academic study, go out of their way to prevent anything in their structure looking even vaguely like it might be represented by the Oroborus. In logic it has been referred to as the "vicious circle."[6] Indeed, so subversive is the Oroborus considered to be that I had considerable difficulty finding it in dictionaries or on the web.

However, design is not a classical study, which is why it is not always admitted as a subject for study at some universities. And the reason it is not admitted is that the academics see it is not a subject in their sense. And they're right: design is not a classical study because study of it involves this Oroborus-like recursion—the main theme of this article, and of the Practice of Practice that it is intended to cast a little light on.

VI Practising Practising

If there are problems associated with recursion, why not avoid it? In particular, why consider our particular recursion, the practice of practice?

One reason we cannot avoid these problems is that design is an action. While it's true there's usually an outcome, design as a process (a verb) is a prerequisite for that outcome, so we need design-the-verb in order to attain design-the-noun. From the point of view of the practitioner—the architect or designer actually involved in design-the-verb—evaluations of design-the-noun's outcome objects in terms of their performance doesn't tell us how to improve them, only what's wrong and what's right.

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[5] The depiction of the animal eating its own tail (suggesting a self-sustaining eternity) is not limited to the West. It has appeared in Chinese, Japanese, Indian and South American Indian cultures (and perhaps others), as can be seen on the web site: http://abacus.best.vwh.net/oro/ouroboros.html

[6] For a wonderful examination of vicious cirlces, see Hughes and Brecht (1978).

If we are to try to improve our skills as designers, we need an approach which helps us design-the-verb better: that is, to (re)design our designing so that the object outcome, the design-the-noun, is better. This is a recursion.[7]

The area of design-the-verb in the profession is normally called practice, which is what I am calling it here. It is an interesting choice of word, for it suggests that we know it's an activity that needs improvement as an activity: practise makes perfect. (Fortunately, the spelling—s for the verb, c for the noun—expresses the difference between verb and noun quite explicitly.)

When we talk about the practice of practice, that is still a practice, so we practise that: the practice of practice of practice. And so on and on. We build endless layers of practice on the latest (but only for a moment, until we practise on it) shell of the recursion of our practice, while we have less and less time for (and even awareness of) the original practice that we chose fatally, once, a long time ago, to practise on, reflexively. This is an onion with layers ever increasing outwards. This is the problem of recursion. And this is the problem with recursion.

So, in the end, if we wish to improve our ability to act, there's little option but to consider recursion. Considering it, if we find it leads to enormous difficulties, we should consider changing the other sources of these difficulties rather than dismissing recursion. When the rules don't accommodate something they should, the rules may need to be changed.

Yet most design research, and most programmes of advanced academic study, have concentrated on design-the-noun. We have developed criticism etc., so we have tools for judgement, but little that tells us how to improve. We deal with that which can appear (literally) objective (our evaluation of the designed object, i.e. design-the-noun), rather that that, most certainly subjective, aspect in that it must involve an actor—how to act.

VII Endless Recursion.

Consider for a moment, if you will, another recursion.

We have experiences and we remember them. Since we live in a world of our own experiences, when we remember we are both recreating an old experience and having a new one—recreating the old experience as experience. Remembering again, we recreate the old experience, but we may also recreate the experience of recreating that old experience.[8]

And so on.

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[7] It is also closely related to the difference between the model of (a noun) and the model for (a verb). These were introduced to me in conversation by Gerard de Zeeuw. Although a concept he frequently uses, I've yet to find an appropriate reference.

[8] The critical questions in developmental psychology are how we come to fix the flux of our experience into singular objects (and concepts), and how we build relationships between these objects and concepts. The appreciation of the significance of these two questions is what makes Jean Piaget such a vital thinker. Piaget solved this through recursion, and von Foerster's work on Eigen-operations (see later) was a response to this, as was my PhD, which von Foerster noted contained the first calculus that described Piaget's processes. See Piaget (1955), Glanville (1975).

For every memory we have, we have not only the recreation of an experience, but the new experience which is that recreation. This is a formulation of one aspect of learning and thinking.

Let us take an ideal example—ideal not in the sense that it's what we'd prefer, but in a more philosophical sense—and consider its implications. Imagine that we are the sort of eidetically cursed person who remembers everything, and remembers it "accurately." Then, for every experience of our lives, there is a memory, and the experience not only of recreating the experience the memory is of, but also of recreating. For every experience we now have two more experiences. And these will be remembered.

Ad infinitum. You see the problem. Each memory balloons into a potential infinity of memory experiences, and, given that each of these experiences takes even the tiniest finite amount of time (and perhaps some sort of space for some sort of storage), our lives become filled with memory experiences and memory experiences of these memory experiences, so we die trapped in our memories of memories of memories…of memories of…

VIII Dealing with (near) Infinity

There are a couple of ways that we can deal with this mushrooming, and the endlessness of the cycling back. It is these that cybernetics has collected together to help us deal with recursion, which we have discovered has been thought an abomination, threatening human endeavour.

The first was brought to cybernetics by Heinz von Foerster, and is rather technically termed "Eigen operation," which leads to "Eigen-values" made by "Eigen-objects." Although "Eigen" is the German for self, it is also (coincidentally) the surname of one of the major investigator of Eigen-operations: Manfred Eigen. Eigen-operations lead to the reproduction of unchanging values, regardless of where you start from. One important illustration is in the description of the orbits that electrons go into, which are strangely discrete and well defined, with no intermediate orbits. They are said to have Eigen-values

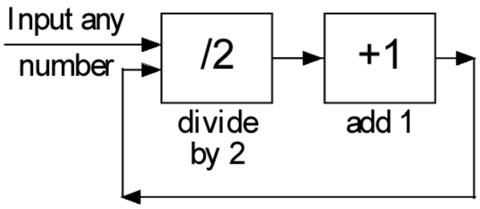
The second, much less technical, is a metaphor for the relationship between an endless output and a definable generator of that output. I do not know where this came from, and I may be the source. Certainly, the metaphor I will use is (as far as I know) mine.

IX Eigen-Operations

Eigen-operations describe behaviours that tend, over time, iteratively (recursively) to a particular value: the Eigen-value. Let us look at an example which von Foerster often used as an illustration (von Foerster 1977).

> Think of a number (for convenience, between -10 and +10, though any number at all will do).
> Divide this number by 2, and add 1 to the outcome.
> Take the result and repeat this process (i.e., divide by 2 and add 1).
> Und so weiter!

Here's a diagram of this:



No matter what number you begin with you will end up approaching and, in the limit, reaching the value 2. Thus, 2 is the resultant Eigen-value of the Eigen-operation divide by 2 and add 1, applied recursively. The Eigen-object is the whole thing: the process and the final value.

You don't believe me? Then do it! (Hint: if your starting number is 2, it works very elegantly and transparently.)

What is described by this (and any) Eigen-operation is a behaviour: the behaviour of a system that runs a recursive operation giving a number as an output, which it then re-inserts so the number is reprocessed (this is the source of the recursion), and emerging as a new number until its behaviour becomes self-reproducing. So it's actually a collection of behaviours that tend towards just one stable behavioural value, the Eigen-value which expresses the Eigen-behaviour.

And the magic is that this system, through recursion, arrives at something that repeats and is stable: an unchanging behaviour. And this gives us a reason to stop the recursion, for, no matter how much more we repeat the recursion, the system will always give the same output. The recursion has reached a stable (that it, self-reproducing) value.[9]

X Wheels and Tracks

More often than not, there is no Eigen-value for a recursive chain of behaviours, although there is always some sort of "fulcrum" (fixed point).[10] Sometimes we may not even want such an outcome After all, we may not want to close down the behaviours so that they converge on one value: we may prefer something that's more freewheeling. While we may not always have the choice, we know that not every recursion leads to an Eigen-value.[11]

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[9] I have developed a smiliar argument in terms of that deeply cybernetic (but often misunderstood) device, the Black Box. see Glanville 1982.

[10] The mathematician Lou Kauffman, long an aficionado of von Foerster, comments as follows (personal communication):

"Of course most recursions oscillate or worse! On the other hand.

> THEOREM. EVERY RECURSION HAS A FIXED POINT.
> PROOF. LET THE RECURSION BE GIVEN BY X ----> F(X).
> LET P = F(F(F(F(F(...))))).
> THEN F(P) = F(F(F(F(F(F(...)))))) = P.
> QED

The problem is in interfacing this wisdom with our chaotic and oscillatory existence! I see the interaction of us mortals with this theorem as one of the great jokes that Heinz played on us as nascent cyberneticians."

[11] Gordon Pask, Mike Robinson and I wrote a book of things to do with pocket calculators, for those who'd bought them without having any use for them. Several of the games were based on the notion of recursion,

I have a metaphor for this. We can consider the potential endlessness of recursion as like the track of a bicycle wheel on the damp sand of a sandy beach (Glanville 1994).

We can consider this track as something in its own right, or we can consider it as the output (the expression) of some sort of process, device, generator. In the case of the bicycle (should this be a monocycle?), this device is a wheel. A wheel rotates. When it touches the sand, it moves, leaving an endless trace. This is an example of what in cybernetics is called a machine: a machine is just something that gives an output, and there are many sorts of machines with more or less predictable outputs. Some, indeed, have no predictable output at all, and some are essentially chimera. So we're not talking a form of mechanical determinism here.

We can examine a continuous and endless behaviour by regarding it as the output, the trace, of some machine. If we can invent such a machine, we can account for the behaviour not as dauntingly endless, but as the result of some small process, device, generator—machine!

The magic of this is that, given that it's our invention (our design) which is based on our own observation of our own outputs, we have a way of describing in finite terms a process that will generate an infinite output, or a life's work!

You can think of the Eigen-operation like this: round and round it passes the result of its computation, a wheel.

The wheel is the form that explains what we now understand as the trace of a behaviour that is the track. To refer back, the unchanging process of human reproduction produces the endless output that is the whole of humanity.

XI Finding the Practice

The two examples taken from the cybernetics of cybernetics give us two ways of handling a recursive process by which we, ourselves, can understand our own practice by reflecting on it. They give us a metaphor by which we can grow and understand our growth and our understanding (of that growth).

Eigen-operations give us the notion that by considering our work, and then considering it again in such a way that we include the earlier considerations in a recursive concatenation, we may approach a stable value—by which is meant that we can arrive at a result that repeats itself. Such a value in our work (its Eigen-value), remains constant through our questioning. It may, therefore, be taken as a fixed point in our practice. We find a deeper understanding, an underlying one which we had not expected, and which derives from exploring our own work in our own terms with an insistence and rigour that denies us the trite and the trivial, the easy way out.

Wheels give us generative forms. They allow us to look at a recursion not as daunting endlessness but as a small engine that produces that endlessness. This is economy indeed.[12] Instead of considering the behaviours we create a mechanism that generates these behaviours. When we can find that in our practice, we have found how our practice works: the practice of

exploring and demonstrating it, and showing a range of behaviours typical of recursive systems. See Pask, Glanville and Robinson (1980).

12 This is essentially how scientific generalisation works.

our practice. This understanding is powerful not because it is something that happens, but because we make it for ourselves, in our own terms. What we find is not "true" because all we are creating is an explanation that might generate the output we observe. But, in systems such as these, that old-fashioned "truth" is not what we are looking for.

Of course, some may feel it is possible to be more radical—to give up aims at convergence, and to continue in the recursion until they feel like stopping. Just say when! And why not? The reason, I think, is that we need reason—we feel more secure when we believe we have justification. But that is not a matter for this article—it belongs in the space beyond, which is somewhere else altogether!

Understanding these two cybernetic devices that handle recursion, we are enabled reconsider our practice, in order to improve it. By understanding those deep (and hidden) fixed points in what we do, we are able to consider how to change them—by, for instance, emphasising them, compensating for them, or trying to replace them (that is, acting as a result of our own critical evaluation).

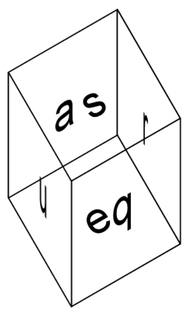
We gain access to ways of understanding what of value to us in how we practise, and of how we can account for making this, which go deeper than the usual approach: i.e. telling us of some theme in our work. This process transcends our limited imagining, for it makes us look deeper, finding surprise and wonder.

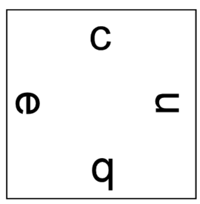
Von Foerster (1977) had a couple of witty verbal expressions of the notion of being what you say. Consider the following two sentences:

> This sentence has thirty one letters.
> This sentence has thirty three letters.

Are they what they say they are? You can count on them being that!

What, then, do you make of a dodekahedron? If a dodekahedron is properly accounted for, shouldn't a square rather be called a cube; and a cube a square? Can you count on them?





Or a lemon yellow Citroën?

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In our world as designers this recursive, reflective process is deeply set. As designers, some of us make educations for designers: we are attempting to design designers (or, rather, to help them design themselves). When we look at practice and try to improve that practice by practising on it, we are involved in the practice of practice: for we design, consider our design and improve it by designing on the basis of what we have: and when we look back, our designing was based on (an earlier instance of) our designing, which is a recursion. If we build theories, and then consider what it is to build theories, we theorise about theorising.

IV Cybernetics of cybernetics

There is one subject that has made a special feast of this recursive, reflective process. This is cybernetics.[3] In 1968, that remarkable anthropologist Margaret Mead (one of the founders of cybernetics in the 1940s) gave the inaugural address at the founding of the American Society for Cybernetics. This was a big, auspicious event, attended by many very distinguished people and was held under the auspices of the American Association for the Advancement of Science meeting that year. Mead's address was entitled 'The cybernetics of cybernetics' (Mead, 1968). As she remarks in this paper, some time earlier she had asked an incredulous Society for General Systems Research if it should not consider itself as a system. Here, she suggests that the fledgling society should define itself by a cybernetic analysis of what such a society might wish to be.

But behind Mead was that same old magician, Heinz von Foerster. It was von Foerster who gave Mead her title. He, as the moving spirit in fledging the new society, had both invited and briefed Mead. And it is to von Foerster, more than any of the others who were involved, that the development of the cybernetics of cybernetics is generally and correctly attributed.[4]

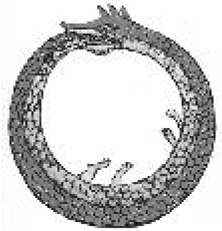
Von Foerster's inspiration was the example concerning observing that I have summarised above. Following the lead he gave Mead, he organised an elective at the University of Illinois in which cybernetic material from earlier days was collected and examined (by learners, ie students) using the sorts of techniques that had been developed in cybernetics. Thus, cybernetics was examined cybernetically, or, to write it out in full, cybernetic material was subjected to a critical evaluation using the techniques and insights that had been developed in and through cybernetics.

The outcome of this elective was an enormous, greatly valued (and-very-hard-to-find-even-though-recently-republished) book, *The Cybernetics of Cybernetics*, originally published in 1974 (von Foerster, 1974). In this von Foerster differentiated between two orders of cybernetics. Old cybernetics, the original, was called first order and was the cybernetics of observed systems. The new cybernetics, called second order cybernetics, was the cybernetics of observing systems. The new cybernetics and second order cybernetics were synonyms for the cybernetics of cybernetics.

Since then, those at the cutting edge of cybernetic thinking have been preoccupied with the cybernetics of cybernetics: reflection, recursion and circularity – dealing with the problems that come with these notions.

V An abomination

Interestingly, this concern is not all new, either. Reflexive, self-referential studies have long been considered an abomination. In earlier times, and particularly in the Middle Ages, a special fictional animal was frequently depicted to embody this evil: the Oroborus (or ouroborus). This, the snake (dragon) that eats its own tail, looks like this:[5]



A depiction of the oroborus from the 15th century Greek alchemical text

Classical subjects, and the form of classical areas of academic study, go out of their way to prevent anything in their structure looking even vaguely like it might be represented by the oroborus. In logic it has been referred to as the 'vicious circle'.[6] Indeed, so subversive is the oroborus considered to be that I had considerable difficulty finding it in dictionaries or on the web.

However, design is not a classical study, which is why it is not always admitted as a subject for study at some universities. And the reason it is not admitted is that the academics see it is not a subject in their sense. And they're right: design is not a classical study because study of it involves this oroborus-like recursionÑthe main theme of this article, and of the Practice of Practice that it is intended to cast a little light on.

VI Practising practising

If there are problems associated with recursion, why not avoid it? In particular, why consider our particular recursion, the practice of practice?

One reason we cannot avoid these problems is that design is an action. While it's true there's usually an outcome, design as a process (a verb) is a prerequisite for that outcome, so we need design-the-verb in order to attain design-the-noun. From the point of view of the practitioner – the architect or designer actually involved in design-the-verbÑevaluations of design-the-noun's outcome objects in terms of their performance doesnÕt tell us how to improve them, only what's wrong and what's right.

If we are to try to improve our skills as designers, we need an approach which helps us design-the-verb better: that is, to (re)design our designing so that the object outcome, the design-the-noun, is better. This is a recursion.

The area of design-the-verb in the profession is normally called practice, which is what I am calling it here. It is an interesting choice of word, for it suggests that we know it's an activity that needs improvement as an activity: practise makes perfect. (Fortunately, the spelling's for the verb, c for the noun – expresses the difference between verb and noun quite explicitly.)

When we talk about the practice of practice, that is still a practice, so we practise that: the practice of practice of practice. And so on and on. We build endless layers of practice on the latest (but only for a moment, until we practise on it) shell of the recursion of our practice, while we have less and less time for (and even awareness of) the original practice that we chose fatally, once, a long time ago, to practise on, reflexively. This is an onion with layers ever increasing outwards. This is the problem of recursion. And this is the problem with recursion.

So, in the end, if we wish to improve our ability to act, there's little option but to consider recursion. Considering it, if we find it leads to enormous difficulties, we should consider changing the other sources of these difficulties rather than dismissing recursion. When the rules donÕt accommodate something they should, the rules may need to be changed.

Yet most design research, and most programs of advanced academic study, have concentrated on design-the-noun. We have developed criticism and so on, so we have tools for judgment, but little that tells us how to improve. We deal with that which can appear (literally) objective (our evaluation of the designed object, ie design-the-noun), rather that that, most certainly subjective, aspect in that it must involve an actor – how to act.

VII Endless recursion

Consider for a moment, if you will, another recursion.

We have experiences and we remember them. Since we live in a world of our own experiences, when we remember we are both recreating an old experience and having a new one – recreating the old experience as experience. Remembering again, we recreate the old experience, but we may also recreate the experience of recreating that old experience.[7]

And so on.

For every memory we have, we have not only the recreation of an experience, but the new experience which is that recreation. This is a formulation of one aspect of learning and thinking.

Let us take an ideal example – ideal not in the sense that it's what we'd prefer, but in a more philosophical sense – and consider its implications. Imagine that we are the sort of eidetically cursed person who remembers everything, and remembers it 'accurately'. Then, for every experience of our lives, there is a memory, and the experience not only of recreating the experience the memory is of, but also of recreating. For every experience we now have two more experiences. And these will be remembered.

Ad infinitum. You see the problem. Each memory balloons into a potential infinity of memory experiences, and, given that each of these experiences takes even the tiniest finite amount of time (and perhaps some sort of space for some sort of storage), our lives become filled with memory experiences and memory experiences of these memory experiences, so we die trapped in our memories of memories of memoriesÉof memories ofÉ

VIII Dealing with (near) infinity

There are a couple of ways that we can deal with this mushrooming, and the endlessness of the cycling back. It is these that cybernetics has collected together to help us deal with recursion, which we have discovered has been thought an abomination, threatening human endeavour.

The first was brought to cybernetics by Heinz von Foerster, and is rather technically termed 'Eigen operation', which leads to 'Eigen-values' made by 'Eigen-objects'. Although 'Eigen' is the German for self, it is also (coincidentally) the surname of one of the major investigator of Eigen-operations: Manfred Eigen. Eigen-operations lead to the reproduction of unchanging values, regardless of where you start from. One important illustration is in the description of the orbits that electrons go into, which are strangely discrete and well defined, with no intermediate orbits. They are said to have Eigen-values.

The second, much less technical, is a metaphor for the relationship between an endless output and a definable generator of that output. I do not know where this came from, and I may be the source. Certainly, the metaphor I will use is (as far as I know) mine.

IX Eigen-operations

Eigen-operations describe behaviours that tend, over time, iteratively (recursively) to a particular value: the Eigen-value. Let us look at an example which von Foerster often used as an illustration (von Foerster 1977).

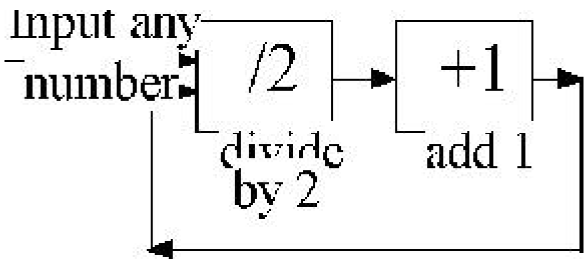
Think of a number (for convenience, between -10 and +10, though any number at all will do).

Divide this number by 2, and add 1 to the outcome.

Take the result and repeat this process (i.e., divide by 2 and add 1).

Und so weiter!

Here's a diagram of this:



An Eigen-object that generates the Eigen-value 2

No matter what number you begin with you will end up approaching and, in the limit, reaching the value 2. Thus, 2 is the resultant Eigen-value of the Eigen-operation divide by 2 and add 1, applied recursively. The Eigen-object is the whole thing: the process and the final value.

You don't believe me? Then do it! (Hint: if your starting number is 2, it works very elegantly and transparently.)

What is described by this (and any) Eigen-operation is a behaviour: the behaviour of a system that runs a recursive operation giving a number as an output, which it then re-inserts so the number is reprocessed (this is the source of the recursion), and emerging as a new number until its behaviour becomes self-reproducing. So it's actually a collection of behaviours that tend towards just one stable behavioural value, the Eigen-value which expresses the Eigen-behaviour.

And the magic is that this system, through recursion, arrives at something that repeats and is stable: an unchanging behaviour. And this gives us a reason to stop the recursion, for, no matter how much more we repeat the recursion, the system will always give the same output. The recursion has reached a stable (that is, self-reproducing) value.

X Wheels and tracks

More often than not, there is no Eigen-value for a recursive chain of behaviours, although there is always some sort of 'fulcrum' (fixed point).[8] The mathematician Lou Kauffman, long an aficionado of von Foerster, comments as follows (personal communication):

Of course most recursions oscillate or worse! On the other hand.

THEOREM. EVERY RECURSION HAS A FIXED POINT.

PROOF. LET THE RECURSION BE GIVEN BY X ——> F(X).

Sometimes we may not even want such an outcome After all, we may not want to close down the behaviours so that they converge on one value: we may prefer something that's more freewheeling. While we may not always have the choice, we know that not every recursion leads to an Eigen-value.[9]

I have a metaphor for this. We can consider the potential endlessness of recursion as like the track of a bicycle wheel on the damp sand of a sandy beach (Glanville 1994).

We can consider this track as something in its own right, or we can consider it as the output (the expression) of some sort of process, device, generator. In the case of the bicycle (should this be a monocycle?), this device is a wheel. A wheel rotates. When it touches the sand, it moves, leaving an endless trace. This is an example of what in cybernetics is called a machine: a machine is just something that gives an output, and there are many sorts of machines with more or less predictable outputs. Some, indeed, have no predictable output at all, and some are essentially chimera. So we're not talking a form of mechanical determinism here.

We can examine a continuous and endless behaviour by regarding it as the output, the trace, of some machine. If we can invent such a machine, we can account for the behaviour not as dauntingly endless, but as the result of some small process, device, generator – machine!

The magic of this is that, given that it's our invention (our design) which is based on our own observation of our own outputs, we have a way of describing in finite terms a process that will generate an infinite output, or a life's work!

You can think of the Eigen-operation like this: round and round it passes the result of its computation, a wheel.

The wheel is the form that explains what we now understand as the trace of a behaviour that is the track. To refer back, the unchanging process of human reproduction produces the endless output that is the whole of humanity.

XI Finding the Practice

The two examples taken from the cybernetics of cybernetics give us two ways of handling a recursive process by which we, ourselves, can understand our own practice by reflecting on it. They give us a metaphor by which we can grow and understand our growth and our understanding (of that growth).

Eigen-operations give us the notion that by considering our work, and then considering it again in such a way that we include the earlier considerations in a recursive concatenation, we may approach a stable value – by which is meant that we can arrive at a result that repeats itself. Such a value in our work (its Eigen-value), remains constant through our questioning. It may, therefore, be taken as a fixed point in our practice. We find a deeper understanding, an underlying one which we had not expected, and which derives from exploring our own work in our own terms with an insistence and rigour that denies us the trite and the trivial, the easy way out.

Wheels give us generative forms. They allow us to look at a recursion not as daunting endlessness but as a small engine that produces that endlessness. This is economy indeed.[10] Instead of considering the behaviours we create a mechanism that generates these behaviours. When we can find that in our practice, we have found how our practice works: the practice of our practice. This understanding is powerful not because it is something that happens, but because we make it for ourselves, in our own terms. What we find is not 'true' because all we are creating is an explanation that might generate the output we observe. But, in systems such as these, that old-fashioned 'truth' is not what we are looking for.

Of course, some may feel it is possible to be more radical – to give up aims at convergence, and to continue in the recursion until they feel like stopping. Just say when! And why not? The reason, I think, is that we need reason – we feel more secure when we believe we have justification. But that is not a matter for this article – it belongs in the space beyond, which is somewhere else altogether!

Understanding these two cybernetic devices that handle recursion, we are enabled reconsider our practice, in order to improve it. By understanding those deep (and hidden) fixed points in what we do, we are able to consider how to change them – by, for instance, emphasising them, compensating for them, or trying to replace them (that is, acting as a result of our own critical evaluation).

We gain access to ways of understanding what is of value to us in how we practise, and of how we can account for making this, which go deeper than the usual approach: ie telling us of some theme in our work. This process transcends our limited imagining, for it makes us look deeper, finding surprise and wonder.

Von Foerster (1977) had a couple of witty verbal expressions of the notion of being what you say. Consider the following two sentences:

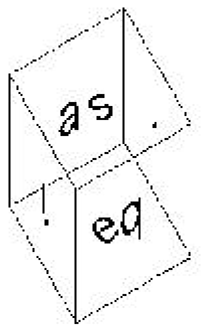
This sentence has thirty-one letters.

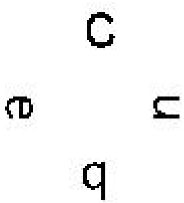
This sentence has thirty-three letters.

Are they what they say they are? You can count on them being that!

What, then, do you make of a dodekahedron? If a dodekahedron is properly accounted for, shouldn't a square rather be called a cube; and a cube a square? Can you count on them?

A square cube and a cube square





Or a lemon yellow Citroen?

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Footnotes

[1] Good introductions to Hilbert and his programme can be found in Encyclopaedia Britannica:

http://www.britannica.com/eb/article?eu=41309

[2] The mathematics and logic of recursion was developed by the Norwegian Thoralf Albert Skolem. Recursive function theory has become ever more significant and important. Think of the following: Adam and Eve were human: their offspring were human: the offspring of their offspring were humanÉwe are human, where our humanity is determined by recursion to a source (Adam and Eve), but is equally determined by the Òoffspring of offspring.Ó Again, Encyclopaedia Britannica is a good starting point. See article at:

http://www.britannica.com/eb/article?eu=64522

[3] For a nice, short introduction to cybernetics for architects and designers, in a way that is related to the arguments presented here, see van Schaik 2002.

[4] See the charming and short account of the basic argument in support of the development of the cybernetics of cybernetics in Foerster (1979). For a summary of wider scope see Glanville (2002).

[5] The depiction of the animal eating its own tail (suggesting a self-sustaining eternity) is not limited to the West. It has appeared in Chinese, Japanese, Indian and South American Indian cultures (and perhaps others), as can be seen on the web site:

http://abacus.best.vwh.net/oro/ouroboros.html

[6] For a wonderful examination of vicious cirlces, see Hughes and Brecht (1978).

[7] The critical questions in developmental psychology are how we come to fix the flux of our experience into singular objects (and concepts), and how we build relationships between these objects and concepts. The appreciation of the significance of these two questions is what makes Jean Piaget such a vital thinker. Piaget solved this through recursion, and von FoersterÕs work on Eigen-operations (see later) was a response to this, as was my PhD, which von Foerster noted contained the first calculus that desc

ribed PiagetÕs processes. See Piaget (1955), Glanville (1975).

The problem is in interfacing this wisdom with our chaotic and oscillatory existence! I see the interaction of us mortals with this theorem as one of the great jokes that Heinz played on us as nascent cyberneticians.Ó

[9] Gordon Pask, Mike Robinson and I wrote a book of things to do with pocket calculators, for those whoÕd bought them without having any use for them. Several of the games were based on the notion of recursion, exploring and demonstrating it, and showing a range of behaviours typical of recursive systems. See Pask, Glanville and Robinson (1980).

[10] This is essentially how scientific generalisation works.