Cybernetics And Human Knowing. Vol. 10, no. 2, pp. 137-146

A (Cybernetic) Musing: In Praise of Buffers

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Not long ago, a colleague of many years asked me a question.[2] He told me of the behaviour of the old lime and horse-hair plaster placed over timber laths that was used until quite recently all over northern Europe as a wall finish. This material has an interesting property: it absorbs and emits moisture, thus helping keep the humidity inside a building within reasonable limits: in other words, it acts as a buffer. What he wanted to know was whether buffers were a topic that had been seriously studied. He assumed they would be part of cybernetics, and, when I heard his question, I immediately replied in the affirmative. I was certain that buffers were part of the area of study of early cybernetics and was sure I had read about them in Ross Ashby's *Introduction to Cybernetics*, for me the subject's essential basic text.

I decided that I'd like to pursue this. Buffers were so clearly cybernetic and yet so surprisingly ignored, that I decided to check back to my sources. I was in for a very big surprise. Opening an electronic copy of Ashby's Introduction,[3] I did a text search and found (to my disbelief) there was no single occurrence of the string "buffer." I was astonished.

The word doesn't appear in the index of my copy of Wiener's *Cybernetics*, or in Bateson's *Steps to an Ecology of Mind*. It's not in the *Cybernetics of Cybernetics* (not even in its parabook). I wondered if I was looking in the wrong culture, but Yelena Saparina's "Cybernetics Within Us" makes no mention. It's not in Pask's "An Approach to Cybernetics." In fact, it's almost nowhere. It's hardly even on the web: the examples in the first 10 pages of a google search seem to concentrate on unplanted strips in forestry (fire baffles), gun recoils, computing uses, and buffer solutions which resist pH change on the addition of acids.

So I looked in the dictionaries. My *Shorter Oxford Dictionary* gives a first date of use of the word "buffer" as 1835, when it referred to what we might now describe as those shock-absorbing dampers, rather like gun recoils, attached to the ends of railway trucks and carriages.[4] It also referred to one of the better-known applications of the idea, the "buffer state." Such states (nations) were proposed to reduce friction between adjoining large nations, being located between them. For instance, after the First World War, making the German land on the West of the Rhine (e.g., Alsace, Saar) into a separate buffer state between France and Germany was seriously considered. The

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2. Thanks, therefore, to Prof Stephen Gage of UCL for inspiring this.
3. I am profoundly grateful to Alex Reigler, supported by the Principia Cybernetica Project, for putting the whole of Ashby's "Introduction" into electronic form. The full story can be found on the site from which you can download the book in pdf format: http://pcp.vub.ac.be/books/IntroCyb.pdf.
4. There is an earlier, but completely different use of the word, as in the expression "He's an old buffer."

Warsaw Pact countries of the old (twentieth century) order were buffer states for the Soviet Union, and the Korean DeMilitarised Zone works similarly.

Eventually, I looked in Charles Francois's *Encyclopaedia of Systems and Cybernetics* (1997)—which I had reviewed for this journal (1999). His entry under Buffer is concerned with message transmission and particularly comes from the concerns of Information Theory. But, under Buffer Compartment, he has something much more helpful:

> Buffer Compartment
> 'A part of a system which acts as a reservoir for incoming energy, matter or information, such that the inputs enter the rest of the system with smoothed and averaged characteristics.' (T. F. H. Allen & T. B. Starr. (1982). *Hierarchy: Perspectives for ecological complexity.* Chicago: Chicago University Press.)

The quantities of energy, matter or information stored in the buffer compartment are at the free disposal of the system. They can be used by regulatory subsystems when needed. This permits a range of differential responses in a changing environment, an adaptive mechanism sometimes called buffering; and it also opposes wide structural destruction.

From this extraordinary lack of discussion, I learnt two things. Firstly, I was reminded that my memory doesn't always co-incide with other evidence and it's important to check back! And secondly, that I was wrong: buffers have not been a major part of cybernetics.[5] But I believe they should be. And so I propose to start an attempted assimilation here.

The Water Jug

Let me start with a domestic example that shows just how ordinary and everyday buffers are, and introduce an alternative. This will allow me to highlight the main qualities of buffers.

At home we use a water filter attached to a water jug to further purify our tap water. From this jug we fill our kettle. There are two approaches to how to manage this. One keeps the kettle full and the water jug continually recharged. The other empties the kettle, filling it when needed from the water jug, in turn leaving the water jug empty. Often enough, both kettle and water jug are empty and filtered water is not readily available, causing untoward delay in tea making.

These two different approaches can be described in several ways. One of these uses the notion of buffering. The water jug (with filter) is, in effect, a buffer. It takes about 5 minutes to fill the jug through the filter. But as long as it's full or being filled, the kettle can be kept charged, so there's always filtered water to be boiled when it's needed. The water in the water jug is a reserve waiting to be used to refill the kettle, so

5. They are, however, frequently referred to and used in computing.

the kettle need never be empty (although the water jug will be while it's being refilled). This arrangement guards the kettle against being empty: it's a buffer.

The alternative is a version of "Just in Time" (JiT) management. Here, we should be able to predict our needs a little before they occur, and act on this prediction. We would be able to have filtered water in the jug Just in Time to be poured into the kettle, which we would turn on so that the water was boiling at the instant we needed it. This requires an acute sense of timing and an ability to plan ahead, rather than being able to react/respond to events as they occur. And it means there are no further, unanticipated possibilities—there is less possibility of improvising.

Our domestic example demonstrates two things. Firstly, that buffering can be a help; and secondly, that there are other approaches, which (as we shall see) form a constellation of related ideas, a Thesaurus. Such approaches include antithetical ones, such as JiT. This is what I will explore in the remainder of this paper.

Definition

Let us start our exploration with a definition to help us focus. I propose the following:

> Buffers are stores which use either space (a water reservoir) and/or time (a holding period for the settlement of accounts) to modulate the effects of variations in the flow of whatever it is the particular system handles—e.g. water, money, information—particularly by smoothing out extreme behaviours.
> They are in use in many natural and designed systems including computer systems. They are sometimes called dampers (as in, for instance, (car) shock-absorbers, that is dampers on springs).

Buffers iron out differences and smooth out bumps. They absorb, hold and then (later) release in such a way that the effects of extremes are reduced/alleviated: they smooth variation and reduce variety. (Thus, planet Earth is a buffer and moderates climate induced temperature swings. This is why the coldest times of year do not co-incide with the shortest days.)

It will be seen from the above that buffers are common enough (even though I have been so singularly ineffective at finding much information about them)!

They are essentially conservative. The greatest of all buffers is, perhaps, the homeostat: homeostatic systems (including human beings) accommodate vast differences in their environments while remaining, themselves, within a narrow band of accepted and stabilising states/behaviours. The effects of these differences is accommodated within the system so that its behaviour remains more-or-less constant (as, for instance, our body temperature).

Flooding

As a first example, let us consider flooding.

A few years ago, the river channel of the Rhine was so full that large parts of Holland were in danger of imminent inundation. Many people had to be evacuated as the waters rose to within a couple of centimetres of the top of the dykes.

Last (northern) summer, large parts of central Europe were subject to appalling floods. A vast area of China was as close to flooding as Holland was those few years earlier.

And, of recent years, Britain has been visited by a whole string of floods which, while not as large or lethal as those of central Europe and insignificant in comparison to others, cause repeating chaos (for they strike again and again in the same places). At the moment of drafting this paper there were 130 flood warnings in the UK.

There are many reasons for these (near) inundations. The one which is of interest here is the removal of water meadows by the canalisation of rivers. Canalising rivers contains them and controls them. No longer are potentially desirable lands on which, for instance, expensive housing could be built wasted as water meadows. Because the path of the water is controlled by containment, they can be built on. The case in Holland is even more dramatic. A vast part of what is now that country was, once, a variety of extreme (submerged) water meadow!

While there are many factors in such flooding (which I am not competent to discuss or evaluate), one factor is undoubtedly the exchange by which canalisation has replaced the buffer of "soft" banks—water meadows—which, acting as both a sponge and a potential shallow lake, absorbed the excess water, giving it up to the river later, when the flow was low. These water meadows served a purpose. They were buffers. Where there are such meadows, flooding is accommodated and the consequent destruction is minimised. The lack of such water meadow buffers contributes greatly to the damage floods may cause.

There is frequently a beneficial side-effect of using water meadows to buffer us against the destructive effects of flooding. Often the ground so flooded is wonderfully fertile once the waters have receded. In the case of the Nile, a vast civilization was made possible. And then there are those further immensely valuable side effects such as beauty in the landscape and delight in our hearts.

But there are other side effects, too, resulting from the removal of water meadow buffers, which are not so good. The canalisation of rivers has changed where floods happen. In place of the regularly flooded water meadow (traditionally not described as flooded), there is now a new, though perhaps less often flooded, regular flood area. And often this turns out to be the centre of a town.

Markets

A second example comes from the operation of markets. Until recently, the London stock market ran with accounting periods of a fortnight. What this meant was that all bills were settled at two weekly intervals. Stocks and shares bought were paid for then, and the funds from stocks sold became available at these fortnightly points in time. If stocks in the same company were bought and sold within this period, only the difference (profit or loss) was paid. The system worked on trust and was associated with the expression "An Englishman's word is his bond." Anyone who cheated and was caught was drummed out of the stock exchange and would never be allowed back. I have met people who, 60 years on, are not forgiven. They never will be.

The effect of this accounting procedure was to vastly reduce the movement of funds. All accounts were squared up at these fortnightly intervals. This is a buffer. But there was another buffer. Because funds did not come available, and the market worked with a sort of delay, there was a reduced tendency for the markets to suddenly shoot off to the extremes. Panic trading was quite genteel by today's standards. Vast sums of money were not seen to be being moved, so the effect of positive feedback was kept in check. Neither computers nor punters went on Gadarene rampages!

All this changed with the introduction of the real time market brought about by electronic communication and computer dealing (in effect, more or less a JiT system). This meant that the experts believed that they could model the behaviour of the market better, react accordingly at great speed, and thereby play the margins (for instance) to greater profit. The result has been markets where instability and rapid escalations have been common. If they are less common now it is because the computer models and responses are more sophisticated. The market has moved from the relative security of a buffered system to a system of immediate controlling responses; reaction effected without delay.

Stafford Beer touched on this most movingly in his Richard Goodman Lecture, "Fanfare for Effective Freedom," where he talks about the destabilising effect of changing from traditional (time delayed) management to real-time management (Beer 1975).

Another example like this might be email, encouraging immediate communication where instant communication based on immediate responses may be misleading (and may lead to great swings in understanding and emotion). The fact that once an email is sent the sender has washed his hands of it yet can fret about it waiting in the addressee's mailbox just increases the trauma.

Buildings

A third example comes from architecture and building.

At the start of the 1970s it became currency to talk of buildings as environmental filters.[6] By this was meant that buildings protect us from the undesirable external environment (this was before understandings of sustainability were what they are today). Thus, windows gave us acceptable light levels within buildings, as well as allowing a controlled amount of fresh air to enter (in effect, a wind filtering device). A building clearly protects us from rain, thus filtering that out too. It also acts to prevent heat gain and loss.

6. My former boss, Geoffrey Broadbent, tells me that this concept arose in discussions around 1970. An account was written up by Hillier et al (1972).

Heat is an interesting case. Preventing heat loss and gain is normally managed through insulation. Insulation comes about through the structure of the material that divides the interior of the building from the exterior. It used to be mainly a matter of thickness (and mass), though now-a-days it's becoming more a matter of improved thermal performance, generally achieved by making materials that are more and more vacuum-like.

In the case of massive materials, the effect is of a buffer. These materials work as storage heaters: they absorb heat when it's hot outside, but lose it to the inside to keep it warm over the cold nights. During the course of the year they also have an effect: in the summer they keep the inside cooler, in the winter warmer.[7] (This is a faster version of how the Earth acts as a temperature buffer for us.)

Many ecological houses work on this principle. They have a heat store (usually a pit full of boulders) which soaks up the heat generated during the day to release it slowly over the night. By circulating air through this store they can keep the inside of a building warm when it's cold outside, and vice versa—without much further energy requirement. The relative constancy of temperature in the ground—regardless of weather conditions—is a major factor in providing the constant temperature conditions needed for making and storing e.g. great wines. Thus have buffers benefited humanity in the most sophisticated way!

Reservoirs

A final example from the physical world is the use of mountain reservoirs to power electricity generating plant when demand is high. At times of low consumption, electricity is used to pump water up into a reservoir, often in the form of an artificial lake in a mountain range. When demand is high, the water is allowed to flow down again, powering turbines that generate extra electricity as and when required. The mountain reservoir is a buffer designed to alleviate the excesses of demand.

In reverse, the same happens with power sources that are unreliable. Renewable sources such as wind, tide, wave and solar generation peak according to natural phenomena, not our requirements. A buffer is needed between supply surges and actual demand.

Non-Physical Buffers

Buffers do not have to be physical. There is evidence that there are mental and emotional buffers, too, as well as social ones. Buffering is used to regulate the flow of traffic in cities. Most storerooms are buffers. There are all sorts of other examples, just as there are all sorts of counter examples and related phenomena. But there does not seem to be, at least in the realm of cybernetics and systems science, a central study of buffering.

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7. Buffering by heavy construction is not the only factor at play here.

A Research Programme

It would seem, therefore, that there is a clearly distinguished gap in our knowledge, which concerns buffering. Buffers are valuable, and part of a range of ideas that fit together as complements and contrasts. Though it might be argued that buffering is not efficient (it's certainly not fast reacting—that's the whole point), buffers give us a good, steady performance and, very often, some delightful side effects: and who is to say that any measure of efficiency should ignore these side effects? Therefore, I would like to call for a major research programme into buffering (together with related concepts).

Such a research programme would consider the following.

Firstly, how buffering works. Clearly this involves the use of time delays to cancel the extreme effects of swings either by using up what is stored in the buffer (and then replenishing it), or by allowing positive and negative to even out. There are certainly models of these processes already well developed in engineering and hydrology which may port to other disciplines—or may not. However, any research programme into the cybernetics of buffering would need to take into account non-mechanical systems in which humans are part of, or even the whole system. There are almost always humans in cybernetic systems, and many of their interactions are mental and/or emotional. The point is that the notion of a buffer has potential over the widest of ranges of application.

Secondly, there are common characteristics in such models.[8] It is important to consider these. If my definition above (or any other) is accepted, experience tells us that we will discover surprises in it. It is important to consider not only the effect of buffers on the systems they buffer, but also how they do this: their modes of action. This includes looking at different types of buffer: for instance the water meadow/sponge is quite different to the homeostat, the first being essentially passive and potentially offering a side benefit (fertile land); the second being active and applying actions internally to redress the balance. Breakdown conditions, in particular, are critical. Buffers break down. Think of the overheating of the homeostatic system that is the human body that can be caused by disease, which in turn can lead to death—in our terms, the ultimate breakdown. It is important to understand the conditions under which this is most likely to happen.

Thirdly, buffering, as indicated above, is a notion connected to other notions in some kind of network of relations. Some of these concepts are antithetical (e.g., buffer vs JiT, for instance); some related (e.g., buffer and filter). The appropriate way of thinking is not just in terms of similarities. For this reason I suggest using a Thesaurus type of arrangement, in which related concepts are placed as thesis, antithesis and at points between.[9]

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8. which is why they can all be thought of as buffers.
9. Unfortunately nowadays many a Thesaurus just deals in synonyms and near synonyms. But Roget's intention when he developed the first Thesaurus was to show the relationship of ideas across the full range, and the antithetical word was as much part of all his entries as the synonymous ones.

Fourthly, and another reason for the Thesaurus proposal, is the exploration of the values of buffers and related concepts, in particular regarding their potential ranges of application, and thus benefit. It is important to know not only what the rival yet complementary concepts are, but the conditions under and circumstances in which one or another is likely to be more helpful.

Buffering and Cybernetics

It is possible that the connection between buffering and cybernetics is not clear from the above. As a conclusion to this piece, I shall indicate the connection.

Cybernetics is concerned with control. In early cybernetics, the concern was to show how to control systems effectively. This is the major concern driving Wiener's book, and what is embodied in Ashby's "Law of Requisite Variety." A little later, interest expanded to include the limits of what is controllable. This was also, above all, down to Ashby, who applied Bremmerman's constant to show that many systems are, in principle, uncontrollable. Later still, it became apparent that control in a circular system exists only between the components (and not by one of another).

Buffering is one way we deal with systems we cannot control, for whatever reason. We can consider the opposite of buffering as control. We remove buffers that we have used, historically, when we come to believe that we can build adequate models that allow us to effectively control (buffers cope with a lack of variety). This is precisely what (first order) cybernetics sets out to do and is one reason it is so important to understand the limits to the controllable So we channel water to replace the wasteful use of land that we come to see water meadows as being. Buffering is a strategy that allows us not to force control when we can't make it work. In effect, buffering is an approach to the dissolving of problems: given time, they go away and everything evens out.

I am suggesting that, if history tells us anything, it tells us we cannot be sure of our models. Therefore, we should be careful. But I have also argued in this journal that there are benefits in being out of control, that is, in living with unmanageability (this is the cybernetics of non-control). Buffers support us in gaining these benefits. We should be careful of rationalising them away when they can allow us to benefit from unmanageability. Nor should we forget the potential for beneficial side-effects.

And we, in cybernetics, should consider control not as a single notion, but, Thesaurus like, as a range that contains synonyms, and moves from thesis to antithesis. And, at the antithetical end to control, where we will find buffering, we also find, strangely, that buffering is a sort of anti-control without a controller. It would be interesting, also, to examine where the limits to this sort of anti-control lie.

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Appendix: definitions of the term "Buffer."

Random House Dictionary, 1971

Buffer

(2) any device, material, or apparatus used for a shield, cushion, or bumper… (3) any intermediate or intervening shield or device reducing the danger of interaction between two machines, chemicals, electronic components, etc.… (5) any reserve moneys, negotiable securities, legal procedures, etc., which protect a person, organisation. or country against financial ruin (6) one who protects and shields another from petty matters or the brunt of anger or criticism… (8) Computer Technol. an intermediate memory unit for temporarily holding computer data until the proper unit is ready to receive the data, as when the receiving unit has an operating speed lower than that of the unit feeding the data to it… (10) Chem. a. any substance or mixture of compounds that, added to a solution, is capable of neutralising both acids and bases with out appreciably changing the original acidity or alkalinity of the solution… (12) to cushion, shield or protect (13) to lessen the adverse effect of; ease.

Buffer state

a small state lying between potentially hostile larger areas.

International Encyclopedia of Systems and Cybernetics, (Charles Francois) 1997

Buffer

A device introduced into a communication system to allow asynchronous communication.

L. Brimm comments: "A buffer preserves message sequences. The buffer discipline is as follows:

-The sender may always send a message

-The receiver may always receive a message, provided the medium is not empty

-The order of receiving messages is equal to the order of sending messages." (1992 p135)

Buffers allow for serialised and ordered communication, avoids bottlenecks and, to some extent, overloads in communication channels.

Buffer Compartment

"A part of a system which acts as a reservoir for incoming energy, matter, or information such that the inputs enter the rest of the system and smoothed and averaged characteristics." (T. F. H Allen & T. B. Starr, 1982, p. 263)

The quantities of energy, matter, or information stored in the buffer compartment are at the free disposal of the system. They can be used by regulatory subsystems when needed. This permits a range of differential responses in a changing environment, a mechanism sometimes called buffering, and it also opposes wide structural destruction.

Shorter Oxford Dictionary, 1993

Buffer

1835. Mech. A mechanical apparatus for deadening the forces of a concussion, as fixed at the front and back of railway carriages, etc. Extended also to contrivances which sustain without deadening the concussion.

Buffer State

a neutral state lying between two others and serving to render less possible hostilities between them.

Merriam Webster's Collegiate Dictionary (on Encyclopaedia Britannica site)

Main Entry: **1. buff·er**

Pronunciation:'b&-f&r

Function:*noun*

Usage:*often attributive*

Etymology:*buff,* v., to react like a soft body when struck

Date:1835

1: any of various devices or pieces of material for reducing shock or damage due to contact

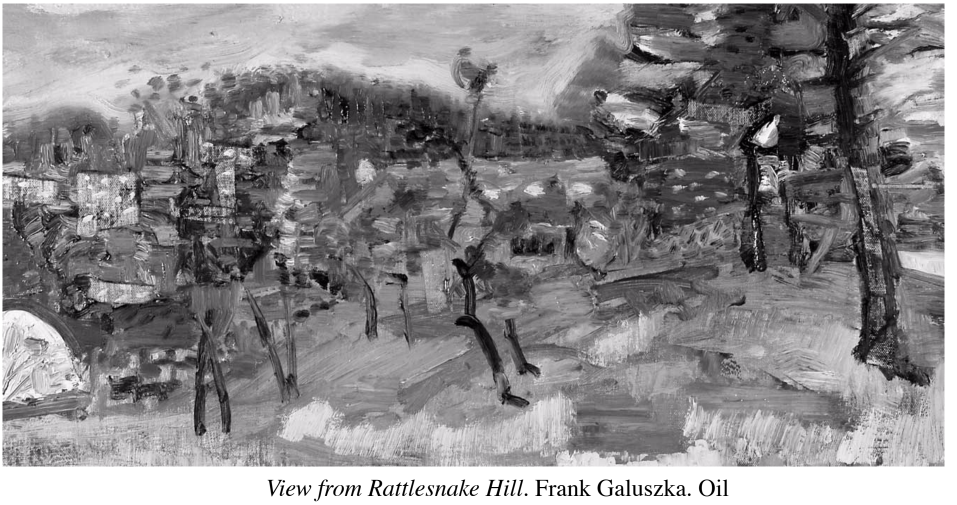
2: a means or device used as a cushion against the shock of fluctuations in business or financial activity

3: something that serves as a protective barrier: as **a: BUFFER STATE b:** a person who shields another especially from annoying routine matters **c: MEDIATOR** 1

4: a substance capable in solution of neutralizing both acids and bases and thereby maintaining the original acidity or basicity of the solution; *also***:** a solution containing such a substance

5: a temporary storage unit (as in a computer); *especially***:** one that accepts information at one rate and delivers it at another

- **buff·ered** /-f&rd/ *adjective*



View from Rattlesnake Hill. Frank Galuszka. Oil