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It is our impression that Gordon Pask's writings cover fundamentals for large parts of the widely expanding fields of Cybernetics and Systems Theory. Thereby, and by his lecturing activites, he has become a unique figure in maintaining a kind of unity of the field of Cybernetics, well in accord with Wiener's view ("control and communication in the animal and the machine"; cf [26]). And that, with fresh ideas, sometimes very personal, somtimes very general, and always very interesting.

In this subjective review of a fragment of Pask's writings, notably within cybernetics, we will, in part, try to account for some of his earlier insights into how we judge the behavior of an artefact (machine) in relation to that of a living organism (animal). And, partly, for his later–conceived conversation theory. Some problems revealed in the latter theory, like how we–in–a–conversation can represent a real behaviour, may well connect back to Pask's earlier studies into the problem whether we can produce artefacts (including thought models) of our behaviours as living beings.

1 *Acting Beyond Verbal Communication*

Once, at a conference on complementarity in Baden-Baden, a person in the audience who had not yet seen Gordon Pask around in a morning session, asked the chairman if Gordon really was present or not – he wanted to ask Gordon a question. Although the audience was large and Gordon well might be there somewhere in the croud, the chairman exclaimed without hesitation: No, Gordon is not here. Had he been, we would all have noticed!

Gordon Pask has a strong personal radiation. He knows it, and uses it to advantage in complementing his verbal lecturing performance with the most incredible topological illustrations – which may make the interpretation of his sentences elevate into a domain of undescribable conceptual reality.

2 *Life, Artefact, and Self-Organization*

As we know, the early Wienerian conception of Cybernetics [26] developed rapidly from feed-back to more advanced forms of self–reference, sometimes even understood as linguistic introspection. Let be with the functioning of language, in terms of communication and control, mostly understood in terms of statistical information and computability. Questions whether animals, and the phenomenon of life itself, can be understood so well that it can be reproduced as artefact were raised (cf [14]).

Already in his first book [15], Pask is well on the way here. He examines the possibilities of reproduction and evolution of *machines*, and embarkes on *self–organizing systems*. He keenly notices the problem of what to "build in" in attempting an artefact which is able to evolve.

For an *artefactual* model of evolution, viewed as a self–organizing system by an observer, who must continually change his reference frame to make sense of it, Pask suggests that ([15]):

> "the rules of evolution are determined by the connectivity of an albeit very flexible computer, a network so constructed that the fabric from which it is made will be irrelevant. On the other hand, if we look at self–organizing systems in the real world, their evolution and development is determined by their fabric and because of this, 'changing our reference frame' comes to mean making physically different – often incomparable – kinds of experiment."

In the evolution of *life* we have an adaptation to a particular fabric, protein, and a particular environment. Pask concludes that a distinction will remain between a self–organizing artefact and life [15]:

> "The distinction between self–organization and life rests in fabric and

> it is significant because we, ourselves, are made from the same stuff as the things *we are prepared to call* 'alive'."

As I understand it, this is an early formulated insight into a principal difficulty of understanding certain phenomena of life so well that they can be reconstructed as artefacts. When a phenomenon under investigation is as complex as life (or language), we have to invoke similar phenomena in the very process of conceptualizing them – which generates principal obstacles against the understandability of "complete" self–organization (as a modelling of life in terms of self-organization would seem to require).

By comparison, Ross Ashby advanced a somewhat related insight, also in the beginnings of the '60's when we were all (Gordon Pask, Ross Ashby, myself, to mention a few) enjoying the stimulating atmosphere created by Heinz von Foerster in his Biological Computer Laboratory (BCL) at the University of Illinois in Urbana. Ashby [1] then even dared to suggest that no machine can be said self–organizing in a certain complete sense. Namely, in the sense that its state behavior function, $f(s)$, is *autonomously* modified, i.e., modified from the state s itself. If, his argument runs, such an autonomy on the contrary were the case, we had to consider specific behavior functions, f_s, parametrized by the actual state s. But then the autonomous machine function, corresponding to both function selection and to function computation, would be $f_s(s)$, i.e., an ordinary (non self-modifying) function $g(s) = f_s(s)$ of one variable, the state of the machine.

At the same time, Ashby is quite aware of the possibility of a *partial* self-organization (although a real argument cannot be given within his formalism). For example, he writes [1]:

> "Thus the appearance of being 'self-organizing' can be given only by the machine S being coupled to another machine ... Then the part S can be 'self-organizing' within the whole $S + \alpha$.
>
> Only in this partial and strictly qualified sense can we understand that a system is '*self*–organizing' without being self–contradictory."

Later on, as we know, further insights into the necessary partiality of self–reference have been gained, somewhat reflected in a shift of interest within self–reference towards "organizational closure" (cf [25, 19]).

Let us see how a general argument, for a Paskian–like observation of the non-universality in our powers of constructing artefacts, can be given with a start in Ashby's attempted formal reasoning.

3 *Universality at the Price of Partiality; Linguistic Complementarity*

We first notice that Ashby [1], without explicitly mentioning it, carries out his reasoning only for machines of a particular kind, namely so called finite state machines (whose behaviors are the so called regular functions). The normal form function $F(n, s)$ for the regular functions, i.e., $F(n, s) = f_n(s)$ (allowing n-enumeration of them), is *not* itself regular in its variables. This is in my view the real reason for Ashby's argument to go through, namely for the impossibility of self-organization within the class of finite automata. However, Ashby's argument does not hold for the class of partial recursive functions, realized by Turing machines.

Indeed, the class of partial recursive functions ψ_n is exceptional in that its normal form function $F(n, x) =_{def} \psi_n(x)$ *is itself* partial recursive in all its free variables. Hence there is a universal partial recursive function $\psi_u(n, x)$, corresponding to a universal Turing machine (u), which n-enumerates precisely the partial recursive functions $\psi_n(x)$. This exceptional type-equality between the normal form and the functions it represents, opens up possibilities for various self-reference phenomena. For example, it is here possible to have a Turing machine perform, partially, operations on itself (cf [7] for examples).

The key to this "universality" is that the objects, the partial recursive functions, are indeed *partial.* By contrast, there is no universal regular function (short for no regular universal function for the regular functions), no universal primitive recursive function, etc, because these functions are not partial but total.

It would seem that the very concept of *partiality* lends itself more nicely to a mathematical understanding than to a "real world" understanding where we tend to look at objects as real just in the sense that they are complete and not partial. Either an object has a given property or it satisfies the negated property. The law of *tertium non datur* prevails. However, in nonclassical introspective physical domains, like quantum physics, ideas of "partial objects" are beginning to crop up.

Although we have simple ideas of partiality in mathematics, like that of a partial order, the concept of a partial recursive function (partially computable function) is, from a realist perspective, more involved in that it violates *tertium non datur*: to say that $\psi_z(x) = y$ holds, may not only be true or false, but undecidable. In evaluating such *partial predicates* we may work along *strong* schemes (where "undecidable" = "true" (or "false") is false). Or along *weak* schemes (where "undecidable" = "true" (or "false") is undecidable). We will return to this issue in section 4.3.

The above Turing machine illustration of "universality at the price of partiality" may also be looked at as a "tension between describability and interpretability" within the involved programming language, where descriptions are programs for the universal Turing machine (u), and interpretations are the corresponding computational behaviours (of u). Let us *increase the interpretability* by moving from the partial recursive functions to the total recursive functions, which (unlike the partial functions) are understandable according to a classical function concept. Then the *describalility* is *decreased* in the sense that we cannot any longer describe, within the language, which programs will be interpretable (as total, recursive functions).

These insights, from a programming language context, are *extendable in a general linguistic setting*. That is, with language conceived as a general wholistic phenomenon encompassing, as species, genetic language, programming languages, formal languages, commmunication languages, each satisfying the linguistic complementarity (cf [9, 11, 13]):

> *Linguistic complementarity.* Every phenomenon that can naturally be considered a language contains descriptions and interpretations that are complementary within the language. This means that language is conceived as an ultimate whole which is non–fragmentable within itself into parts, descriptions and interpretations, which may yet be fully described in a metalanguage, provided one such exists. There are various related ways of looking at the complementarity:
>
> (i) as descriptional incompleteness: in no language can its in-

terpretation process be completely described in the language itself;

(ii) as a tension between describability and interpretability within a language;

(iii) as degrees of partiality of self–reference (introspection) within a language: complete self–reference within a language is impossible;

(iv) as a principle of "non–detachability of language".

Arguments leading to this thesis, as well as demonstrations of its validity for known language species, may be found in [11].

When developing the introspective sides of cybernetics, we must constantly remind ourselves of the "non–detachability of language". Language cannot be isolated as an object of study the way a classical physical object can. Again, we cannot totally free ourselves from language and think as if our toughts, if communicable, were beyond that which a shared language allows.

Pask's, as well as Ashby's, early conclusions are compatible with a move from a computational perspective to a linguistic.

4 *Unforeseen Context–Dependencies in Human Artefactual Activity*

We will here, by way of an interdisciplinary selection of related views, developed somewhat later, illuminate Pask's and Ashby's early insights into the context–dependence of human artefactual activity. We will also see how these dependencies, usually unforeseen according to a classical cybernetic perspective, may be diminished by increased introspection. A total independence, or a total autonomy of an artefact, is however not possible – compare the nondetachability of language (or the other views of the linguistic complementarity).

4.1 *Induction; its Dependency on Relevance and Similarity*

Popper, in considering the idea of building an induction machine, writes in [22], page 48:

> "Placed in a simplified 'world' ... such a machine may trough repetition 'learn', or even 'formulate', laws of succession which hold in its 'world'. If such a machine can be constructed (and I have no doubt that it can) then, it might be argued, my theory must be wrong; for if a machine is able to perform inductions on the basis of repetition, there can be no logical reasons preventing us from doing the same.
> The argument sounds convincing, but is mistaken. In constructing an induction machine we, the architects of the machine, must decide *a priori* what constitutes its 'world'; what things are to be taken as similar or equal; and what *kind* of 'laws' we wish the machine to be able to 'discover' in its 'world'. In other words, we must build into the machine a framework determining what is relevant or interesting in its world: the machine will have its 'inborn' selection principles. The problems of similarity will have been solved for it by its makers who thus have interpreted the 'world' for the machine."

Undoubtedly, this is a clear insight into the problem of understanding induction so well that we could use it to realize induction artefactually. Popper's emphasis on *relevance* and *similarity* is also found in Pask's writings, both early and later (cf for example [18]).

We assume here that Popper means that we do *not* have such an objective understanding of our own "relevancy"– and "similarity"– processes that we can build corresponding machines, but that we instead have to tell the presumed induction machine what we consider relevant in an actual situation. Late investigations support this view of a necessary linguistic relativization of "relevance", "similarity", as well as of "induction" itself. Although these processes are at play in the description and interpretation processes within a language, they cannot be sufficiently well described in that language to admit artefactual realization [10].

4.2 *Information; its Dependency on Choice of Universal Interpretor*

In its general linguistic understanding, information is a concept which emanates from, and reflects, the fact that language is nondetachable as well as partly introspective (see [12]).

This may not make much sense if we are thinking of information in its technical sense (like statistical information). But in cybernetics, “on the score of ‘information’, it might be wise to broaden the definition”, as Pask suggests in [20]. In moving towards semantic information, we find along the way, in “algorithmic information”, phenomena indicating a somewhat surprizing dependency on the interpretor in spite of its being considered “universal”.

Consider a specific language, namely a programming language L with programs as descriptions and interpretation processes performed by universal Turing machines U (defined by their Gödel numbers u). In this context, an object $\mathbf{m}$ is a finite string of symbols (output symbols of some U), and will as such be represented by a number z. Thus, a description of z is a program x (a number) which makes U compute z, such that $\psi_u(x) = z$, and $s(z,u)$ is the shortest such x which makes U compute z. Notice that $s(z,u)$ is a total function, i.e., one that is defined for every z.

In [5] we gave the first proof of the *non*computability relations for the total function $s(z,u)$, and thus obtained a direct metamathematical support for taking the length of the shortest description, $|s(z,u)|$, as a complexity measure in this computability context. That is, with the complexity of z reflecting a difficulty of describing z, it would be a countermeasure to find it easy, in the sense of an algorithmic possibility, to generate descriptions of complex z.

Kolmogorov proposes in [3] a similar “algoritmic approach” in suggesting the complexity, or information, measure $K_u(z) = |s(z,u)|$ for a string z relative to U.

Perhaps disturbed, as a mathematician, by the dependency of $K_u(z)$ on the choice of U, Kolmogorov [3] procedes to prove that the difference between the complexity measures for any two universal machines is finitely bounded:

$$|K_{u_1} z \; - \; K_{u_2} z| \; \leq c_{u_1 u_2},$$

where the finite number $c_{u_1 u_2}$ does not depend on z. This last result is taken to imply that there is no essential difference, in an asymptotic sense, between the complexity measure defined relative to one universal machine or another. In that sense, the index u may be dropped from the complexity measure, then denoted by Kolmogorov $K(z)$.

Concerning this asymptotic invariance result, leading from $K_u z$ to Kz, the following remark may be of relevance. According to [5, 6], for each u, $|s(z,u)|$ $(= K_u z)$ is only computable on a finitely restricted domain. Thus, there is a maximal, computable, complexity value for each u. It may then, from a strict computational point of view, not be of much help to know that the difference between $K_u z$ and some other $K_{u_1} z$ is finitely bounded, because this does not prevent the difference from being larger than, say, the maximal complexity values. The moral is to keep the u-index in $K_u z$.

It is even more important to keep an explicit u-relativization in considering that $|s(z,u)|$ has a profound significance in the case where the object $\mathbf{z}$ lets itself be inductively known via partial observations of it. By way of an example, consider a recursive function, $\mathbf{f}$: $N \to N$, as an object which lets itself be observed via initial segments z of its enumeration as a sequence of argument-value pairs. The problem of inductively inferring a description, or program, of $\mathbf{f}$ from large such initial segments is a well studied one, where $s(z,u)$ plays a significant role for the programming strategy (cf [8]). Here, the programming language (reflected in the choice of u) is of importance.

Concerning interpretability in a natural language, we may similarly look at the secrets in our inductive capacities as hidden in the properties which the language obtains in its adaptation to the class of environments in which it works. That is, hidden in the sense that they cannot be explicitly described in the language.

4.3 *Partial Truth; its Dependency on Choice of Gödel numbering*

Kripke's theory of truth [4], which has proved quite fertile, deals with a particular problem of linguistic introspectability, namely whether it is possible to conceive of languages admitting theories containing their own truth predicate, $T(x)$. Normally (cf previous section) a predicate is conceived to be true, or false, for any object in the language, and we then know from Tarski [23] that there is no language admitting a theory with its own truth predicate. Kripke considers the possibility of a *partial* truth predicate, $T(x)$, which may be undefined for some sentences, x, thus admitting truth-value gaps. He is forced to admit that it is still necessary to ascend to a metalanguage in order to make certain assertions about the object language – which cannot be made there in spite of its containing a T-predicate.

Now, Cain and Zlatan [2] establish results about an unexpected "context"–dependence of formal theories with partial truth predicate. By way of example, the sets which are (least fixed point) definable under weak Kleene valuation (cf previous section) do depend on the choice of the Gödel numbering of the vocabulary.

Further, the authors show that these dependencies can be made to vanish by a slightly increased introspection which is obtained, not in directly moving to a strong Kleene valuation, but by introducing a certain new function symbol involving the Kleene $T(z, x, y)$ predicate. That is, the predicate on which the "universality" concept for Turing machines builds.

5 *Conversation Theory*

Pask's conversation theory (cf [16, 17, 21]) may seem to reflect a move in his later cybernetic thinking. Namely, towards *conversation* as the basic unit of psychological/educational observation. It is a deep study of psychological, and sociological, processes which are involved in our cognitive operations and which can be exteriorised so as to be observable as segments of dialogue and behaviour.

Indeed, in moving from observation as that which can be written down in an observation report (like in physics), to observability of segments of dialogue and behaviour, Pask widens the cybernetic domain. In physics, we usually assume with Bohr that the observation report is written in a simplified "ordinary language" permitting an unambigous interpretation. But how could a dialogue, although representable in words, be well understood? Furthermore, how are we to think of "observable as segments of dialogue and behaviour"? Does this mean that not only the dialogue but also the behaviour is assumed describable? Or, is complementarity involved?

As we have seen, Pask grasps a complex domain, and it may be helpful for the discussion to first conceive of a *purified conversation*, similar to the one we have in a Turing test for possible distinction between an artificial and a human intelligence. As we know, the Turing test [24] focuses on what conclusions could be drawn from observation of a (teletyped) pure dialogue between a machine (some very advanced computer) and a man. The dialogue, we assume, consists in an exchange of sentences in a language rich enough to contain also programs with respect to some universal Turing machine (assumed present on both sides of the communication channel).

If we increase the complexity of the machine, it may engage in a dialogue from which it may be difficult to infer that the machine is not human. Recalling, from the linguistic complementarity, that there are properties of the language which cannot be communicated in this purified conversation (admitting only sentences), it is likely that a decisive dialogue will concern introspective capacities. Here we have a difference. Human introspection reflects its learning phases, while machine introspection, which is programmed, is of a different sort. As argued in section 4.1, even if the machine is programmed for inductive inferencing, it must fall short in comparison with human inductive powers which do reflect properties of the language (obtained by evolutionary adaptation) – which are beyond our describability and programmability.

Now, the set up of this purified conversation is such that it primarily allows conversation about what has been learnt (programmed). Even if the conversation itself may yield further inductive inferences, these are of a special sort in that they are entirely based on descriptions (sentences), never on interpretations themselves. By contrast, in a real life situation, a human being, in learning from (undescribed) reality, may be said to take part in a different type of conversation, a conversation with a nature which exposes itself as a reality (which may of course also contain linguistic phenomena). To come to grips with this situation, it may be necessary to invoke language in its complementaristic conception, and to conceive of reality according to some *linguistic realism* (see [13]).

It is my impression that Pask, in his conversation theory, tries to overcome the indicated limitative restriction of a purified conversation. For example, he explains in the introduction to [17]:

> "The previous monograph [16] deals with the history and implementation of techniques designed to exteriorise cognitive operations, especially those of learning and teaching, so that they can be observed as segments of dialogue and behaviour."

It would seem that Pask here broadens up the concept of the conversation from the above pure conversation to one containing segments of dialogue *and* behaviour. At the same time, however, he restricts it to such segments which can be *observed*. In a first understanding, this may seem to bring the conversation back to that of the pure type.

Yet in his later writings, particularly in [21], Pask illuminates his conversation theory in terms of *complementarity*, which he looks at as "peaceful coexistence". This may indicate that he wants to attach conversation theory to his earlier basic insights into the existence of human cognitive behaviours which cannot be completely realized in artefacts (cf sections 2 and 3). Yet, it is my impression that his conception of complementarity may be too narrow.

6 *On Pask's View of Complementarity*

In [21], Pask gives several examples, from his conversation theory, of what he considers different kinds of complementarity.

> "My expository predilection is to start with an entity known as procedure, and a principle, *Ap*, of application, over a to-be-specified and intertwined ensemble of procedures. *Ap*, of a procedure, gives rise to a process, this to a product and this is an important kind of complementarity. By edict, there is no process which does not give rise to a product and there is no product which is not produced by a process."

Let us see how this translates in a programming language with a universal Turing machine as interpretor: "applying a computation procedure (program) – having the universal machine start working on the program – gives rise to a (computation) process, this to a product (a function value for example) and this is an important kind of complementarity".

From section 3 we know that it is important, in realising universality, to allow procedures (programs) which are not well interpretable as total objects. I.e., of allowing nonterminating processes, or processes without product. Thus, Pask's requirement, that every process give rise to a product, appears to be a stipulation of well-interpretability of procedures, rather than a complementarity enforced by the nature of languages. According to linguistic complementarity, this stipulated well-interpretability can only be achieved at the expense of a lowered describability. That is, the corresponding procedures cannot be specified in the language.

Pask's converse requirement, that there is no product which is not produced by a process, i.e., that there is no function value which is not computable from a program, may seem to reflect Church's thesis.

In referring to the linguistic complementarity, Pask writes [21]:

> "To grossly summarize the matter, the issue is his linguistic complementarity of which there are at least two kinds. One of the two is 'transcendable', meaning that it is possible to construct a metalanguage, over the language in which the complementarity is stated, thus to observe the complementary entities in motion, the other is 'not transcendable', so that the stated complementarity is, in a good sense, not exposable."

This is a well received summary. Yet, the involved concept of "construct" may carry with it a meaning which I do not intend. I do not usually look upon languages as "constructed" in a sense of being products of processes caused by procedures. Languages (in the complementaristic sense) do *evolve* in a way which cannot be described in terms of procedures. There is only one kind of linguistic complementarity. It obtains for every language. Whether it is transcendable or not, i.e., if a metalanguage has or has not evolved, is primarily a matter of evolution of other languages.

Pask relates to his own view of complementarity as follows [21]:

> "In the former and transcendable case, which is characteristic of my own contribution, the term complementarity means that if one thing or event exists then so does another thing or event, for example, process and product. This usage, implying necessary coexistence, is, perhaps, fundamental. "

It would seem that Pask conceives of complementarity, in terms of co*existence*, from the view of a realism where existence is essentially independent of observation. In referring to the transcendable case, he assumes that in this reality it is possible to *construct* a metalanguage in which he can achieve both well-describability and well-interpretability with respect to the object language.

In my own understanding of a linguistic realism [13], the involved linguistic complementarity implies a fundamental difference between evolutionary processes and processes which result at application of procedures. Here reality occurs as a complementaristic conception caused by descriptive incompleteness. Without that conception, i.e., in trying to account for reality descriptively (cf also a purified conversation), we could only conclude that it was at best partially describable.

7 *Pask's Unifying Performance*

Already in this brief subjective view of a fragment of Pask's writings, it is apparent that he covers a lot of ground. His unifying efforts are truly remarkable – and urgent in that the fields of cybernetics and general systems are becoming very diversified and complex.

Yet, there is a price to this, at least according to the view "universality at the price of partiality". And Pask finds it natural to enquire into the nature of his conversation theory in comparison with other scientific domains. In [21] he writes:

> "Whether or not Conversation Theory is scientific as a theory is debatable. Conversation Theory is a theory which deals with mind, for the greater part with conversational interactions, verbal or not, visual or not; consequently, its data are mostly distinct from those of physics, say. It is particularly important to stress this point, since if Conversation Theory is deemed to have scientific status, this status is not based on some ludicrous 'pseudoscience', in which ...
>
> Instead, any scientific claim for Conversation Theory is based upon firmer ground, namely, possession of a structure which is similar to, in places isomorphic with, the structure of theories more or less universally regarded as scientific, ...
>
> It is safer for this moment at least, to say that Conversation Theory is a formalizable theory, a portion formalized, and leave the matter open for later discussion."

Indeed, to say that a theory is formalizable does not mean that it is complete. Compare Kripke's theory of truth (section 4.3), where formalizability enforces truth to be described with a *partial* truth predicate (implying linguistic or contextual dependencies). Again, compare quantum mechanics, whith observation processes included in its own domain, leading to its formal description being incomplete with principal difficulties as to its understandability as dealing with phenomena of a physical rather than linguistic reality (cf [13]). To capture introspective cybernetics by means of a conversation theory, where observation is broadened to inductive inferencing based on segments of dialogue and behaviour, is still more complex.

What may be valuable here is an *understanding* of the cybernetic incompleteness and partiality phenomena which are exposed in the very conception of a conversation theory. An understanding, that is, going beyond formalizability and into the fundamentally linguistic nature of human life.

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