Analysis and synthesis
as theory of product realization

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Aristotle: Nicomachean Ethics
Book 3

We deliberate not about ends but about means. For a doctor does not deliberate whether he shall heal, nor an orator whether he shall persuade, nor a statesman whether he shall produce law and order, nor does any one else deliberate about his end. They assume the end and consider how and by what means it is to be attained; and if it seems to be produced by several means they consider by which it is most easily and best produced, while if it is achieved by one only they consider how it will be achieved by this and by what means this will be achieved, till they come to the first cause, which in the order of discovery is last. *For the person who deliberates seems to investigate and analyse in the way described as though he were analysing a geometrical construction* (not all investigation appears to be deliberation- for instance mathematical investigations- but all deliberation is investigation), and *what is last in the order of analysis seems to be first in the order of becoming.* And if we come on an impossibility, we give up the search, e.g. if we need money and this cannot be got; but if a thing appears possible we try to do it.

Translation by Ross

Proposition

- The ancient method of analysis and synthesis (A & S), developed by Greek geometers, is able to provide – and has provided - stimulus and ingredients to the theoretical and methodical aspects of design disciplines.
- It provides thus a proto-theory of design

Terms analysis and synthesis…

- **are here not used in their current dictionary meaning - we try to reach the original meaning**
- **For example, according to Wikipedia**
  - **Analysis** generally means *the action of taking something apart in order to study it.*
  - **Synthesis** […], is commonly understood to be an integration of two or more pre-existing elements which results in a new creation.

Geometrical analysis and synthesis

- ANALYSIS is that procedure by which a proposition is traced up, through a chain of necessary dependence, to some known operation, or some *admitted* principle. […] The reverse of this process constitutes *Synthesis*, or *Composition,* […] Analysis, therefore, presents the medium of invention; while synthesis naturally directs the course of instruction.

Source: Leslie, J. 1821. Geometrical Analysis, and Geometry of Curve Lines. Edinburgh.

Some history

- Ancient Greek geometers, Euclid
- Greek philosophers fully aware: Aristotle, Plato
- Pappus: the only remaining longer account
- Translation of Pappus into Latin in 1589
- Medieval science: Interpretation of Aristotle etc.
- Newton: scientific method
- Descartes: analytical calculus
- Enlightenment: Aristotle and other legacy science not fashionable
- Progressively, the term analysis hijacked into other uses

Pappus on analysis and synthesis

Now analysis is the way from what is sought - as if it were admitted - through its concomitants in order to something admitted in synthesis. For in analysis we suppose that which is sought to be already done, and we inquire from what it results, and again what is the antecedent of the latter, until we on our backward way light upon something already known and being first in order. And we call such a method analysis, as being a solution backwards.

In synthesis, on the other hand, we suppose that which was reached last in analysis to be already done, and arranging in their natural order as consequents the former antecedents and linking them one with another, we in the end arrive at the construction of the thing sought. And this we call synthesis.

Now analysis is of two kinds. One seeks the truth, being called theoretical. The other serves to carry out what was desired to do, and this is called problematical. In the theoretical kind we suppose the thing sought as being and as being true, and then we pass through its concomitants in order, as though they were true and existent by hypothesis, to something admitted; then, if that which is admitted be true, the thing sought is true, too, and the proof will be the reverse of analysis. But if we come upon something false to admit, the thing sought will be false, too. In the problematical kind we suppose the desired thing to be known, and then we pass through its concomitants in order, as though they were true, up to something admitted. If the thing admitted is possible or can be done, that is, if it is what the mathematicians call given, the desired thing will also be possible. The proof will again be the reverse of analysis. But if we come upon something impossible to

Features of analysis and synthesis

1. The starting and end points of analysis qualitatively different
2. Unity of two directions of inferences: backwards for solution and forwards for proof
   1. Regressive inferences: analysis (resolution)
   2. Inferences forwards: synthesis (composition)
3. Does not ensure that the solution can be found: iterative
4. Two types of analysis: theoretical and problematical
5. Decompositional (configurational) analysis
6. Transformative (interpretive) analysis

Justification for the proto-theory claim

- Various features of A & S have recently been rediscovered in various design sciences, but without any connection to it

The starting and end points of analysis qualitatively different

Ancient
- "we suppose the desired thing to be known" - we do not know whether it is possible or can be done
- "…until we on our backward way light upon something already known…"

Modern
- Concept (C): a proposition that has no logical status, we cannot know whether it is true or false
- Knowledge (K): propositions in the knowledge space (K) have a logical status

(Hatchuel's C-K theory)

Interpretation

- Helps to distinguish between: where the expansion of concepts is needed versus where the expansion of what is known is needed
- In so doing, accurately positions the creativity needed – as well as unpredictability!

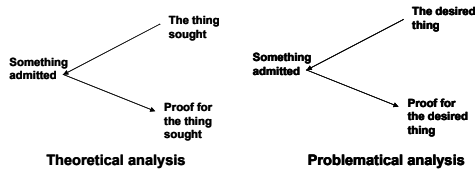## Two types of analysis: theoretical and problematical

Ancient
- "Now analysis is of two kinds. One seeks the truth, being called theoretical. The other serves to carry out what was desired to do, and this is called problematical."
- That is, problem to **prove** and problem to **find** (Polya)

Modern
- Finding the concept
- Detailing and evaluating it

Theoretical and problematical

The thing sought

Something admitted

Proof for the thing sought

Theoretical analysis

The desired thing

Something admitted

Proof for the desired thing

Problematical analysis

Interpretation

- Design consists (at least) of two types of activities:
  1. Finding an overall solution or solution candidate, and
  2. Providing a proof for it
- The previous called "concept", "architecture", etc. (and a bit misleadingly synthesis)
- The latter called in various names, evaluation, analysis, etc.

Unity of two directions of inferences

Ancient

- "…we call such a method analysis, as being a solution backwards."
- "the proof will be the reverse of analysis"

Modern

" The left tail of the V represents the specification stream where the system specifications are defined. The right tail of the V represents the testing stream where the systems is being tested (against the specifications defined on the left-tail). The bottom of the V where the tails meet, represents the development stream. "

Interpretation

- As in geometry, claims that in addition to finding the solution, its proof is *always* needed, i.e. validation and verification.

Establish business and system requirements, solution concept, and validation plan

Prepare solution specification and verification plan

Prepare functional specs and verification plans for configuration items

Prepare detailed designs and verification procedures

Decompose and define

Integrate and verify

Validate

Validate

Validate

Validate

Trial system

Integrate system

Assemble items

Build items

(From PAConsulting Group's Web site)

Regressive inference

Ancient

For in analysis we suppose that which is sought to be already done, and we inquire from what it results, and again what is the antecedent of the latter, until we on our backward way light upon something already known and being first in order. And we call such a method analysis, as being a solution backwards.

Modern

- Means-ends analysis

Interpretation

- Requirements engineering etc. value based approaches: QFD

Inferences forwards

Ancient
- …we suppose that which was reached last in analysis to be already done, and arranging in their natural order as consequents the former antecedents and linking them one with another, we in the end arrive at the construction of the thing sought.

Modern
- Validation, verification
- Prototyping

Interpretation

- Synthesis may be in thought or in deed
- 4D modelling, prototyping etc. are based on this idea of synthesis as a proof

Does not ensure that the solution can be found: iterative

Ancient
- "But if we come upon something impossible to admit, the problem will also be impossible."

Cutting edge
- Agile

Interpretation

- Design is (almost) never a one-way journey, but implies zig-zagging.

Decompositional analysis

Ancient
- From which parts (lines, angles, points, etc.) a figure is made up, and which relations exists between those parts
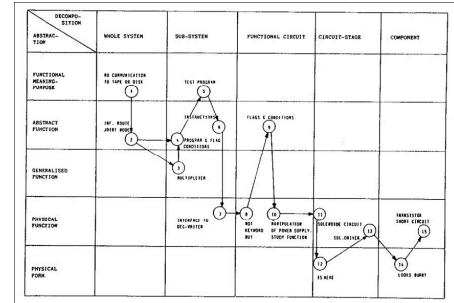
Modern
- Decomposition, or Work Breakdown Structure, as the foundational idea of project management

Interpretation

- Whole-parts relationship
- Metaphysically, a thing-based consideration – what the construct is?
- May contain the relations between parts or not

Rasmussen

Transformative analysis

Ancient	Modern
• Auxiliary lines	• Transforming the problem into a form susceptible to analysis
	• Expanding the concept space
	• Etc.

Interpretation

- The least clear feature – several possible interpretations
  - Transforming statements into a logical form, i.e. into a form susceptible to analysis (!) etc. (Russell)
  - Expanding the "concept space"
  - Analyzing (!) the implications of the original problem (Kant's analytical proposition)
  - Seeing the problem in its context
  - Seeing design as as a progressive transformation of the representation of the object to be designed
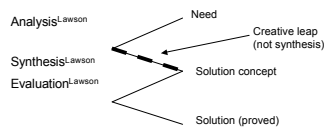
The present usage of A&S

1. (Impoverished) dictionary meaning: breaking down and putting together
2. In different/dislocated meaning: Pugh, Lawson
   1. *analysis = rational stage*
   2. *synthesis = creative stage*
3. In clear contradiction to the ancient method: Hubka & Eder
   1. "synthesis = moving from ends to means"
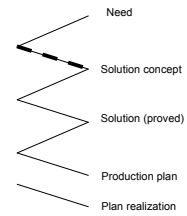4. Informed by the ancient method: ?

A & S and the present design methodology

- Total amnesia: nowhere in the current design, project management etc. literature is the ancient analysis forwarded
- On the other hand, the progress of design methodologies seems to consists of getting the features of A & S to be realized in a more transparent and structured way

Lawson and A & S

Analysis^{Lawson}

Synthesis^{Lawson}
Evaluation^{Lawson}

Need

Creative leap
(not synthesis)

Solution concept

Solution (proved)

How is planning related to this?

Need

Solution concept

Solution (proved)

Production plan

Plan realization

How is A/S related to TFV?

– Generally, A/S provides a detailed theory for V!
– A/S does not cover F issues.
– A/S partially contains T issues, and helps to understand and develop them further.

Current confusion with the two problems in design

- Lawson, Cross
  – Analysis – Synthesis - Evaluation
- Pugh
  – Synthesis – Analysis - Synthesis
- Systems engineering
  – Synthesis - Analysis

Conclusions

- A case of epistemological dilution: A & S has provided crucial stimuli for various fields, but the method itself has been forgotten
- Consequence: Sciences of design are hollow - the core theory has been missing
  – Fragmentation: design science, SE, NPD, CE, PM, etc.
  – Re-inventing the wheel
  – Little accumulation of knowledge