Patchwork Approaches to Concepts and Different Scales

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Project Information

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Introduction

Many concepts of science seem to have no general distinct meaning, but work more like a set of patches forming a patchwork.

E.g.: *hardness* is used differently for different materials (metals, rubber etc.).

We use such concepts polysemously.

The different uses are not only due to different materials, but also due to different scales.

In this talk we link the discussion of patchwork concepts to the discussion of different measure theoretical scales.

Contents

Polysemous Concepts and the Patchwork Approach

Polysemous Concepts in Science

We often use polysemous concepts in science. E.g.:

- temperature: the mean kinetic energy within the domain of gases at the molecular scale; the *frozen order* of solids at the polymer scale;
- homology: for the domain of genes and that of body parts partly based on the same techniques of searching for a common ancestor and an evolutionary transformation series;
- gold: with different specific properties such as that of being (non-)catalytic at different scales such as the macro, nano, and atomic scale.

Traditional Approaches to Polysemy

Speaking about polysemy, one should distinguish between the *standing* and the *occurrent* meaning of a word:

- standing meaning: is the meaning the word has as a type
- occurrent meaning: is the meaning a word has as particular tokens of that word-type

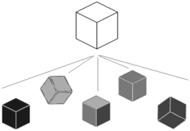
Given this distinction, we can classify three semantic approaches to polysemy (cf. Vicente 2018, pp.949ff):

- Literalism: each word-type has exactly one literal standing meaning; differences in the occurrent meaning are only due to pragmatic factors.
- Underspecification (thin) account: the standing meaning of a word is underspecified with respect to its occurrent meaning.
- Overspecification (rich) account: the occurrent meaning of a word is just a part (or a selection) of the total standing meaning of the word.

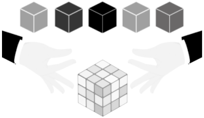
Traditional Approaches to Polysemy

Literalism

Underspecification



Overspecification



Problems of the Traditional Approaches

Traditional semantical approaches fail to characterise polysemous concepts of science adequately:

- Vs. Literalism: there is no privileged meaning; e.g.: temperature
- Vs. Underspecification: general abstract representation exist but do not encompass all occurrent meanings; e.g. homology;
  also general meanings could be too unspecific to be useful;
- Vs. Overspecification: there is no total meaning from which individual features are recruited; e.g. hardness (see below)

The Patchwork Approach: Structure

The *patchwork approach* to polysemy avoids the assumption of a privileged, underspecified or overspecified standing meaning.

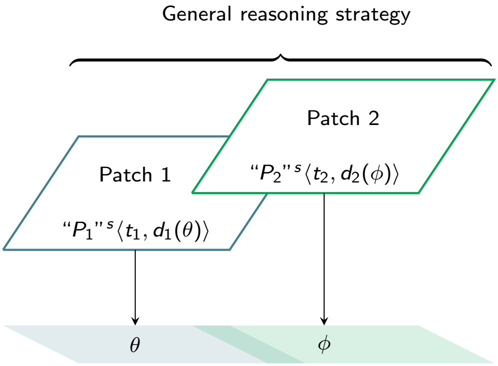
Rather, it suggests to focus on the initially highlighted elements: **s**cale, **t**echniques, **d**omain, and specific property ($\boldsymbol{\theta}$):

$$\overbrace{\mathsf{Term}^{s}\langle t, d(\theta)\rangle}^{\mathsf{Patch}}$$

And consider it like the material structure of a quilt. Each patch in a quilt is stitched to neighbouring patches, without there being a central piece.

The Patchwork Approach: Structure

Scientific Concepts as Patchworks



(cf. Haueis 2021)

Technique (t)
Instructions how to use experimental or mathematical tools to achieve result

Domain (d)
Class of entities to which the concept applies

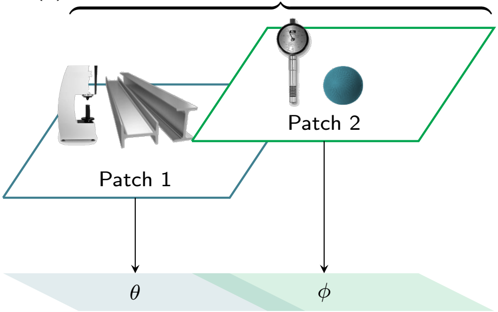
Property (θ, ϕ)
Objective feature of scientific interest (e.g. quantity, disposition, mechanism)

Scale (s)
Spatial, temporal or energetic interval at which a property is instantiated

The Patchwork Approach: Example

Scientific Concepts as Patchworks: Example of "Hardness"

Reasoning strategy: (a) mechanically intervene on material
(b) find quantity describing resistance to intervention



(cf. Haueis 2021)

Technique (t)
Indenter test
Durometer test

Domain (d)
Metals
Elastomers

Property (θ, ϕ)
Load causing plastic deformation
Load causing elastic deformation

Scale (s)
Macroscale
Macroscale

The Patchwork Approach: General Advantages

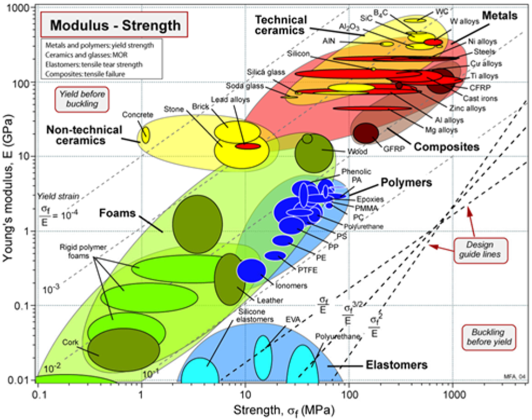
Like in everyday situations, polysemy in science does not hinder communication (Falkum 2015).

⇒ Scientists are trained to use polysemous words in scale-dependent technique-involving, domain-specific, and property-targeting ways (Haueis 2021).

Generalised patchwork approach offers norms which govern when extending a patch is legitimate (Haueis 2021).

⇒ Normatively constrained pluralism: Scientists can use legitimately constrained patchwork concepts without eliminating general term (Taylor and Vickers 2017).

Linking Multiple Patches: “Hardness”

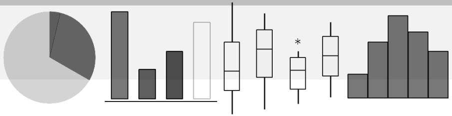


(Chart from CES EduPack 2010, Granta Design Limited, Cambridge, 2010)

- Material property charts combine multiple patch-specific hardness quantities (here: yield strength and modulus of elasticity)
- Scientists move back and forth between patches to understand how specific kinds of material resist intervention
- Examples of linking patches only considers partitions within the same measurement scale (here: Pascal)

The Patchwork Approach to Concepts of Different Scales

Measure Theoretical Scales



Interestingly, the problem of scale-dependent polysemy of concepts has been mainly discussed with respect to scales of the same type.

However, there is also a problem of scale-dependent polysemy with respect to scales of different (measure theoretical) types.

We can distinguish between different types of scales (cf. Stevens 1946):

- qualitative: nominal
- comparative: ordinal
- quantitative: interval and ratio

Take, e.g., the concept of *temperature*. We distinguish high temperature (nominal), higher temperature (ordinal) and temperature to degree r (interval/ratio); other examples: *hardness*, *length* etc.

To speak of *temperature*, *hardness*, *length*, is to use a polysemous concept.

Measure Theoretical Scales: Mathematical & Philosophical

(Mathematical) measure theory studies ways of linking concepts of different scales as well as their epistemological features (philosophical).

Questions of the mathematical measurement theory:

- Which quantities are fundamental?
- How can we measure a quantity (structural presuppositions)?
- etc.

π

Questions of the philosophical theory of measurement:

- How to define quantities (operationally)?
- What is the role of conventions in measuring?
- Are quantities real in the sense of being independent of attempts to measure them?
- etc.

φ

Example of Linking Concepts of Different Scales: Length

Measuring length is a form of fundamental measurement.
Here is in a nutshell how it works (simplified presentation of Hempel 1974):

- We pick out a *quasi order relation* such as *. . . is longer than or equally long to . . .*: L; this relation is . . .
  - *transitive*: if zLy and yLx, then also zLx,
  - *reflexive*: xLx,
  - *connex*: xLy or yLx

  . . . and allows us to define an equivalence relation $=_L$: $x =_L y$ iff xLy and yLx

π

- We constrain a measure l by the general conditions:
  - if $l(y) = l(x)$, then $y =_L x$
  - if $l(y) > l(x)$, then yLx
- and achieve this in a unique way by fundamental metrisation via . . .
  - setting $l(y) = l(x)$ if $y =_L x$,
  - relying on an additive physical operation $\circ$ (concatenation): $l(y \circ x) = l(y) + l(x)$,
  - defining a unit: l(international prototype measure) $= 1$

Example of Linking Concepts of Different Scales: Length

This allows us to measure directly any length that (a) is a multiple of our unit or (b) whereof the unit is a multiple.

We can also fix "incommensurable" lengths indirectly (e.g. the diagonal of a square with the unit length).

What is important for fundamental measurement is the existence of an operation $\circ$ that shares relevant features with mathematical operations (addition, multiplication: commutativity, associativity etc.).

Furthermore, it is important that we have "enough" objects that stand in relevant relations to each other. E.g.: if no two x, y are $x =_L y$, then *fundamental metrisation* will only assign l(international prototype measure) $= 1$.

In the later case, information of direct measurement of the quantitative scale does not exceed that of the ordinal scale.

Linking via Derived Metrisation: E.g. Temperature

There are also other ways to measure/metrisise: via derived metrisation.

E.g.: temperature t: regarding the classical concept no "natural" operation is additive: $t(y \circ x) = t(y) + t(x)$
non-natural: combining individual substances and heating the combined substance up to the sum of the individual temperatures;

However, "deriving" t via l of the extension of mercury in a bar brings in additivity.

Within the range of mercury's liquid aggregate phase, this "derivation" is conventional (coordinating definitions). The mapping also correlates empirically with the volume of gas of the same temperature under fixed pressure:

$$t(x) = f(v(x))$$

Based on this correlation, the definition also extends to cases not covered by mercury's liquid aggregate phase. This derivation is then empirical.

Polysemy due to Different Types of Scales

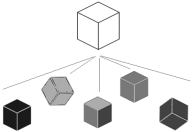
We have seen a bit how measure theory links concepts of different scales.

Now we can ask how to best account for the polysemy of concepts for different scales?

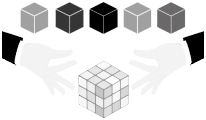
Recall, we have discussed four approaches:

Literalism

Underspecification



Overspecification



Patchwork

In the following, we argue in favour of an interpretation *Patchwork*.

Vs. Literalism

Literalism: one scale is fundamental and the others are derived or can be eliminated.

We find such claims in early philosophy of science (Carnap) but also in philosophy in general regarding theoretical concepts (in the debate about Lockean bridging cf., e.g., Kyburg).

Problem: outline above makes clear that also fundamental quantities are constituted on the basis of (elements of the) ordinal and nominal scales.

Only in very general cases there is a "logical bottom-up linking" of different scales:

metric $\Rightarrow$ quasi order $\Rightarrow$ equivalence relation $\Rightarrow$ partition/categories

Vs. Underspecification

Concepts of different scales have different features:

- nominal: thresholds (or threshold elements)
- ordinal: order (vs. nominal) and generality (vs. interval/ratio; see, e.g., discussion in economics regarding preferences vs. utilities and industry of impossibility theorems)
- interval/ratio: quantity

To rely only on a general concept of measurement (e.g. measurement as the construction of mappings from empirical into numerical structures) is unlikely helpful to specify the occurrence meanings for different scales;

Vs. Overspecification

Scales can be specified via their transformation properties; these become less specific from quantitative to nominal:

- ratio: invariance under multiplication by a positive number
  (e.g.: $cm = 2.54 \times in$)
- interval (linear): furthermore invariance under constant shift
  (e.g.: $^\circ F =^\circ C \times 9/5 + 32$)
- ordinal: any monotonically increasing transformation
- nominal: any one-to-one substitution transformation

However, as we have seen, the construction of the scales for the different concepts (*length*, *temperature* etc.) is not simply one from an overspecified concept to a specification of the different concepts of the different scales.

The Patchwork Approach

Rather, instead of thinking about a single set of defining features, one should think of several features that are "locally linked".

We think that this can be seen quite well with respect to the problem of *selecting a unit*/standardisation in measurement ...

... which brings us back to the philosophical theory of measurement.

The Patchwork Approach: Standardisation

Standardisation involves choices among nontrivial alternatives.
E.g.: the choice among different thermometric fluids or among different ways of marking equal duration (Tal 2013, 2020).

Problem: Appealing to theory to decide which standard is more accurate would be circular, since theory cannot be applied prior to a choice of a measurement standard.

- ⇒ "problem of coordination" (Van Fraassen 2008)
- ⇒ "problem of nomic measurement" (Chang 2004, chpt.2)

Conventionalists attempted to escape the circularity by positing a priori statements, known as "coordinative definitions".

Problem: it supposes that choices of measurement standard are arbitrary and static, whereas in actual practice measurement standards tend to be chosen based on empirical considerations and are eventually improved.

The Patchwork Approach: Standardisation

New philosophical approaches on measurement counter the problem of coordination/nomic measurement by aiming to show that the involved circularity is not vicious (cf. Tal 2020, sect.8.1).

Chang argues that constructing a quantity-concept and standardising its measurement are co-dependent and iterative tasks ("epistemic iteration").

Epistemic iteration as, e.g. in the case of the (pre-scientific) concept of temperature respects existing traditions while at the same time it corrects them (Chang 2004, chpt.5).

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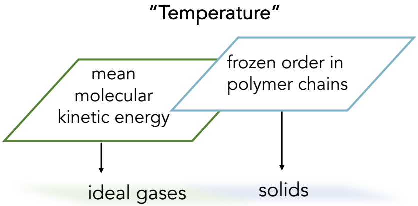
The Patchwork Approach: Advantages

WHY TAKE PATCHWORK STRUCTURES AT FACE VALUE?

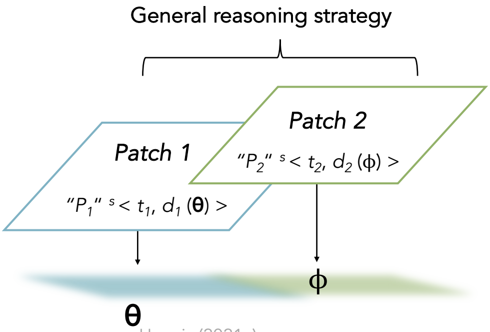
- special case of **polysemy** - multiple related lexical meanings (e.g., "book")
- generating new meanings from old ones: **flexibility of language** (Falkum 2016)
- patches are connected by local links without sharing **core meaning**



- initial meaning easily misdiagnosed as most significant one (Wilson 2017)
- extending reasoning strategy to novel case shifts meaning of word to encode information efficiently

The Patchwork Approach: Key Principles

NORMATIVE CONSTRAINTS ON PATCHES

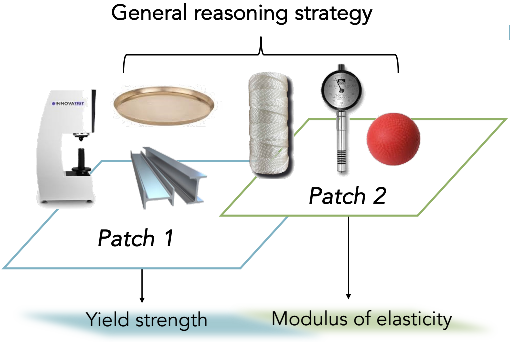


Haueis (2021a)

- **Reliable techniques**
  detect the same property in two entities
- **Homogeneous domains**
  same property assigns entities to extension
- **Significant properties**
  used to describe, classify or explain behavior of entities

The Patchwork Approach: Key Principles Exemplified

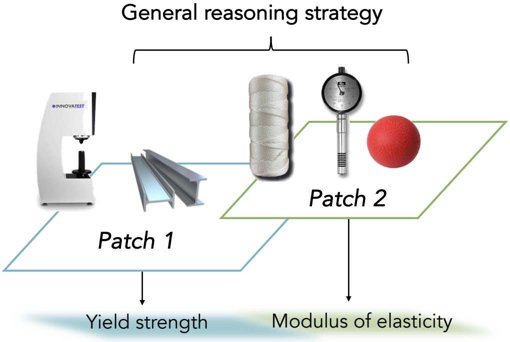
NORMATIVE CONSTRAINTS ON "HARDNESS" PATCHES



- **Reliable techniques**
  Detect same property in different entities
- **Homogeneous domains**
  Same property to assign entities to extensions
- **Significant properties**
  Yield strength & elasticity describe material behavior

The Patchwork Approach: Pragmatic Unity

PRAGMATIC UNITY OF PATCHWORK CONCEPTS



Reuse techniques
Use technique to detect property of another patch

Overlapping domains
Two properties usable for some entities (here: nylon)

Combine properties
Material property charts describe relation between hardness quantities