Epistemic Engineering and the Interplay of Meta-Induction and Abduction in the Justification of Laws of Nature

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Project Information

Talk(s):

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Project(s):

- DFG funded research unit *Inductive Metaphysics* (FOR 2495); subproject *Creative Abductive Inference and its Role for Inductive Metaphysics in Comparison to Other Metaphysical Methods*.

Introduction

Meta-induction: approach to justify induction

Recent criticism: provides only a justification of a single instance of induction

We argue by the help of an optimality principle against this criticism.

Furthermore, we outline how by the help of optimality and shifting from (meta-)induction to (meta-)abduction one might justify laws.

Our investigation is a particular instance of epistemic engineering.

Contents

Epistemic Engineering and Meta-Induction

Epistemic Engineering

Epistemic Means-End Principle:

$$\overbrace{\mathcal{O}(A)}^{\text{ulterior epistemic ends}} \quad \& \quad \underbrace{\Box(A \rightarrow B) \vee (B \mathrel{\circ\!\!\rightarrow} A)}_{\text{epistemic engineering}} \quad \Rightarrow \quad \overbrace{\mathcal{O}(B)}^{\text{derived epistemic ends}}$$

Most important: Make your (epistemic) ends explicit!

Also, apply normative reasoning, e.g.: **Ought Implies Can Heuristics:**

$$\neg\exists B(B \text{ is a means for } A) \;\Rightarrow\; \neg\mathcal{O}(A)$$

The MI-Approach in a Nutshell

1. Hume's problem is about an absolute justification of induction. (Hume)
   Schema: $\mathcal{O}(\textit{absolute success})$
2. There is no means for such an absolute justification. (no free lunch)
   Schema: $\neg\exists B(B$ is a means for $\textit{absolute success})$
3. Hence: We need new epistemic ends. (ought implies can)
   Schema: $\neg\mathcal{O}(\textit{absolute success})$
4. We aim at a relative justification. (Reichenbach)
   Schema: $\mathcal{O}(\textit{relative success})$
5. There is a means for such a relative justification. (meta-induction)
   Schema: $(\textit{meta-induction} \circ\!\!\rightarrow \textit{relative success})$
6. Hence: (Meta-)induction is justified. (means-ends reasoning)
   Schema: $\mathcal{O}((\textit{meta-})\textit{induction})$

Epistemic Re-Engineering: Reichenbach's Vindication

Instead of $\mathcal{O}$(*absolute success*), aim at $\mathcal{O}$(*relative success*)

Skyrms (2000, p.46): "If no method is guaranteed to be successful, then it would seem rational to bet on that method which will be successful, if any method will."

Lightbulb-Example

- You have to bet on some colour.
- Possible states:
  1. No light turns on.
  2. The orange light turns on.
  3. All lights turn on.

Predicting is not sufficient for success, but necessary: Whenever you are successful with your prediction, you would have been also with predicting .

Induction: might fail, but if we are successful, then also by induction

Epistemic Re-Engineering

$\Rightarrow$

Meta-Induction as an Optimal Prediction Method

Meta-Induction

Distinction: Object-induction OI (applied to events) vs. meta-induction MI (applied to methods).

A *meta-inductive method* favors prediction methods according to their observed success rates and attempts to predict an optimal combination of their predictions.

Crucial features of the meta-inductive solution proposal to the problem of induction:

- Is compatible with Hume's diagnosis that one cannot demonstrate the reliability of induction.
- It shows something weaker: predictive optimality of meta-induction in all possible worlds, among all methods that are *accessible* to the subject ('access-optimal').
- The shift to optimality copes with skeptical-scenarios: even in induction-hostile worlds, induction may be optimal ("the best of a bad lot").
- Shift to meta-induction reduces the *inaccessible infinity* of possible methods to the *finiteness* of accessible methods.

Meta-Inductive Justification of Induction

The justification of MI is analytic and 'a priori'. *Per se*, it does not warrant OI, because the possibility of clairvoyants cannot be excluded a priori.

However, *the a priori MI-justification implies an a posteriori justific. of OI:* So far OI was a most successful prediction strategy; thus it is meta-inductively justified to favor object-induction in the future.

Technical results:

Definition

A (real-valued) **prediction game** is a pair $((e), M)$ consisting of:

1. An infinite sequence $(e) := (e_1, e_2, \ldots)$ of events e_n, whose possible values are coded by real numbers: $e_n \in Val \subseteq [0, 1]$.
2. A finite set of simultaneously accessible prediction methods ('players') $M = \{M_1, \ldots, M_m, MI\}$. The M_i are the *candidate methods* of MI. In each round n each method delivers a prediction $pred_{n+1}$ of the next event e_{n+1}.

Meta-Inductive Justification of Induction

Important: Even if events are binary ($e_i \in \{0, 1\}$), predictions may be real-valued, $pred \in [0, 1]$ ('mixtures' of events).

Application: **Probabilistic prediction games**. Here the predictions are probability distributions over event values, evaluated in regard to the true event value.

Success evaluation:

- Deviation of $pred_n$ from e_n is measured by a normalized loss function, $loss(pred_n, e_n)$.
- $score(pred_n, e_n) =_{def} 1 - loss(pred_n, e_n)$.
- $suc_n(M)$ = sum of scores until time n, divided by n,
- $maxsuc_n$ is the maximal success rate of all methods at time n.

Meta-Inductive Justification of Induction

Different variants of MI are possible (Cesa-Bianchi and Lugosi 2006).

Most efficient is **attractivity-weighted meta-induction** *aMI*

$$pred_{n+1}(aMI) =_{def} \frac{\sum_{1 \leq i \leq m} w_n(Mi) \cdot pred_{n+1}(M_i)}{\sum_{1 \leq i \leq m} w_n(M_i)}$$

with cleverly defined success-dependent weights $w_n(M_i)$ (definition skipped).

Major result

Theorem: Universal access-optimality of aMI: For every prediction game $((e), \{M_1, \ldots, M_m, aMI\})$ with convex loss function:

1. (Short run:) $(\forall n \geq 1:)$ $suc_n(aMI) \geq maxsuc_n - 1.78 \cdot \sqrt{ln(m)/n}$.
2. (Long-run:) $suc_n(aMI)$ converges to $maxsuc_n$ for $n \to \infty$.

Three Important Generalisations

The optimality theorem generalizes:

- to *arbitrary non-convex loss functions*, if optimality is explicated in terms of the average success in a *collective of aMI-meta-inductivists*;
- to prediction games with an *unboundedly growing* set of methods;
- **most importantly, to action games**, by identifying each action with the prediction that this action will yield maximal payoff, and the actual payoff with the event;

Challenge of Igor Douven (2022)

He acknowledges the optimality justification, but argues:

Optimality doesn't explain **why** *object-induction is so highly successful*, so strongly superior to non-inductive methods.

For this purpose we need assumptions of *inductive uniformity*, or *lawlikeness*.

They are assumed in Douven's explanation of OI's success by simulation studies.

Douven assumes that the a posteriori justification of OI provides a justification of these inductive uniformity assumptions.

Challenge of Tom Sterkenburg (2022)

No – the optimality of OI is based on **past success** rates and can only justify the belief in the inductive prediction of the **next future event**, but not belief in general inductive uniformity or lawlikeness.

From Optimality to Rational Belief

The general problem: The transition from optimal methods to the justification of particular beliefs generated by them.

Epistemological challenge – **Scepticism & suspension of judgement:**

> *Why isn't it more rational just to act meta-inductively optimal, but to suspend one's belief in the truth or probability of the predictions on which one bases his/her actions?* *(e.g.: stock-market predictions, one might simply "operate" without believing)*

Proposed Solution: (a principle linking optimality-reasoning to norms of (degrees of) belief)

The optimality principle (Schurz 2022)

If *aMI* applied to a candidate set containing some minimally rational methods ($OI \in M$, total evidence E) recommends a prediction *pred*, and ...

- we are forced to act *as if* we have a probabilistic preference for one among all possible predictions,

then it is epistemically rational to infer that *pred* is more probable than all alternative predictions, with probabilities estimated by *aMI over probabilistic predictions*, $P_{aMI}(pred_{n+1}|E)$.

From Optimality to Rational Belief

Condition (*) handles the problem of *suspension of judgement*.

It follows from the requirement of *cognitive coherence*: our *explicit* (degrees of) beliefs should agree with our *implicit beliefs* embodied in our actions.

The antecedent of (*) holds, because choices of actions are implicit predictions.

Transition from justified degrees of beliefs to justified qualitative yes-or-no beliefs:

> *By Locke's threshold condition: H is believed iff* $P(H|E) \geq \alpha$ (> 0.5), *where* α *is determined by the given context (comprehensive debate; most recently Douven 2021).*

Meta-Induction AND the Optimality Principle

How far do we get with meta-induction & the optimality principle?

We argue in four steps and conclude with an objection:

1. The optimality principle leads from the a posteriori optimality of an *aMI*-weighted probabilistic prediction based on past track records, $P_{aMI}(e_{n+1})$, to an a posteriori reason for having degrees of belief according to $P_{aMI}(e_{n+1})$.

   Sterkenburg's objection: Prima facie, P_{aMI} applies only to the *next event*.

2. *But this is not true.*
   Prediction games may not only be applied to the next event, but to finite sequences of future events. The probability functions are formulated for arbitary future events.

Meta-Induction AND the Optimality Principle

Our argument continued:

3. Given that object-induction (OI) is a posteriori justified, almost all probabilistic methods that achieve a significant weight after a sufficient number of test cases n will satisfy the *principle of exchangeability:*

$$P(e_{n+1}|e_1, \ldots, e_n) = P(e_{i_{n+1}}|e_{i_1}, \ldots, e_{i_n})$$

   for arbitrary events $e_{i_1}, \ldots, e_{i_n}$ of the sequence. (I.e.: you might permute indices)
   Exchangeability is a weak inductive uniformity assumption.
   Also, *exchangeability* will be embodied in our actions. For example, we regard it as improbable to win a lottery, regardless of *when* it takes place in time.

4. By the representation theorem of de Finetti (1980), an exchangeable P is identical with an expectation value of statistical probabilities (Schurz 2019, sect.4.4).
   General statistical hypotheses are a weak form of lawlikeness assumption.

Meta-Induction AND the Optimality Principle

Conclusion: It seems that:

> *Belief in weak inductive uniformity (exchangeability) and weak lawlikeness (general statistical hypotheses) is justified by meta-induction & the optimality principle.*

Can we proclaim 'victory'?

Not so easily: The implicit beliefs embodied in our actions cover at most a finite amount of our future – they strech to future generations, but not necessarily to infinity.

One may restrict the inductive uniformity assumption to the practically relevant future and remain agnostic or even counter-inductive in regard to the fast-distant future.

What speaks against *restricted* uniformity/lawlikeness assumptions?

Meta-Induction AND the Optimality Principle

Possible answers: they are less simple, ad hoc, don't cohere with background theories – therefore they are *worse explanations* than general lawlikeness assumptions.

These arguments go beyond what can be justified by meta-induction over predictive success.

The inference to explanations that are better because of *virtues different from predictive success* is an **abductive inference**.

$\Rightarrow$ Before we turn to abduction, we must get clearer about the notion of lawlikeness.

The idea that observed regularities are best explained by *laws of nature* is due to (Armstrong 1983; Harman 1965; Lipton 1991).

The plausibility of this thesis depends on what is meant by "laws of nature" $\Rightarrow$ next section.

Weak versus Strong Lawlikeness

Weak versus Strong Lawlikeness

Compare:

(SL) Salt dissolves in water.	Strongly lawlike. Law of nature, physically necessary.
(WL) All ravens are black.	Weakly lawlike. Depends on contingent conditions.

Note: Comprehensive debate ... authors arguing that genuine laws occur only in physics have (SL) in mind; authors arguing each special science has its own laws have (WL) in mind (Reutlinger et al. 2019; Schurz 2013, sect.6.6)

The output of meta-induction & optimality principle:
at most weakly lawlike generalizations "all, or x% of, Fs are Gs".

Weak versus Strong Lawlikeness

The differences between (SL) and (WL) depend on *background theories*.

(SL) follows from fundamental laws of nature alone.
E.g.: Ionic substances dissolve in polar solvents (given standard temperature, pressure).

(WL) does *not* follow from fundamental laws of nature alone. It depends on (i) laws of nature *and* (ii) on *contingent conditions*, that could be broken by interventions. (There could be a mutation in raven colour genes).

In regard to (WL) we may rightly be unsure whether we should predict weak uniformity only for the next future (next 100 years) or for an indef. future.

Conclusion: (SL) has to be supported by background theories of fundamental laws, containing *theoretical concepts* going beyond observation.

Their just. goes beyond induction and requires theory-generating abduction.

Justification of Theory-Generating Abduction

Instrumentalistic Success

Instrumentalistic success-evaluation of theories: By meta-induction over an aggregated convex measure of success in predictions and simplicity.

Major difference to meta-induction over predictions:
We can observe only the truth value of empirical predictions, not of theoretical laws. *Therefore* the optimality principle developed so far is *too weak* to justify belief in the theoretical part; only in empirical consequences.

Optimality principle for instrumentalistic success: If a theory (or combination of theories) T is justifiably access-optimal w.r.t. instrumentalistic success, and . . .

* we are forced *to act as if we believe in the predictions* of one of the possible alternative theories,

then it is rational to believe in the *predictions of T* (with meta-inductively estimated probabilities).

Instrumentalistic Success

Example – Predictions of moving bodies in gravitational fields:
elliptic orbits of planets, parabolic trajectories of projectiles, etc.
Predictions are justifiable by *induction*, their past truth success is observable.

Explanation by gravitational forces is generated by a theory-generating abduction:
$\Rightarrow$ Is not observable, can only be assessed via their entailed predictions.

The instrumentalist says (Van Fraassen 1980): I believe in the predictions of gravitation mechanics, but not in the reality of forces. I use them as optimal predictive instruments.

Optimality Justifications and Realism

Are optimality justifications confined to instrumentalism?

Or is there an optimality justification for abductive realism?

For justifying belief in the theoretical claims of a theory T, we need a ...

Stronger optimality principle (Schurz 2022)

Suppose meta-induction and the optimality principle recommend a theory T instrumentalistically, and additionally it holds that ...

- ** every accessible alternative theory T* of non-negligible prior plausibility entailing (approximately) the same empirical predictions as T, contains a theoretical sub-model that is (approximately) isomorphic to T

... then it is rational to believe that T's theoretical model is truthlike – at least more truthlike and probable than any of its competitors.

(Strong opt.: general epistemic behaviour (using general principles) should be aligned to "extended cognition" (realist interpr.))

Example 1: Ordinary realism versus the brain-in-the-vat hypotheses.

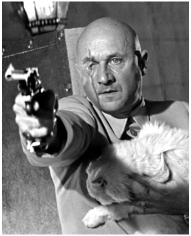
Example 2: Ordinary evolution theory versus (evolutionary) creationism.

Meta-Abduction

Meta-Abduction

The strong optimality principle (**) is about preferring simpler theories (T as an isomorphic sub-model of T^*).

If this is a goal/end of science, it should be made explicit
= epistemic engineering



Meta-Abduction

But this means that $\mathcal{O}$(*relative success*) is not only about the accuracy of predictions but also simplicity.

Once this is made explicit, we can also design a "competition"/prediction game about this
$\Rightarrow$ an account of meta-abduction (cf. Feldbacher-Escamilla forthcoming)

(Above we spoke about applying meta-induction over an aggregated convex measure of success in predictions and simplicity.)

Meta-Abduction and Pragmatism?

Does meta-abduction automatically buy in a great deal of pragmatism (simplicity as a pragmatic factor)?

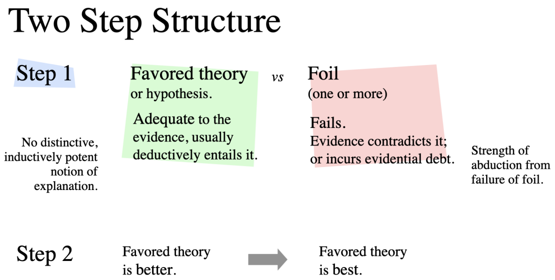
If we include simplicity, plausibility, non-ad hocness etc., then it seems: in principle yes.

However, any form of abduction will do so if *explanation* is not watered down to empirical accuracy.

Let us illustrate this by the help of an example.

Norton-Abduction

The approach (Norton 2021, chpt.9):



Evidential debt . . . why does "adding theory" incur evidential debt?

> *"evidential debt: a supposition needed for the theory to succeed but for which evidence was then lacking" (p.224)*

Epistemic goal: # suppositions : pieces of evidence . . . isn't this pragmatic?

Abduction and Pragmatism?

But such an intake of pragmatism is not necessarily always the case.

At least sometimes we can reduce seemingly pragmatic factors to epistemic ones.

E.g.: simplicity in the context of curve-fitting (cf. Forster and Sober 1994).

Simpler models are less prone to overfit erroneous data.

Meta-Abduction and Simplicity

E.g. for the epistemic value of simplicity:

The estimated predictive accuracy (EPA) of the family of a model F given some data X is determined by:

$$EPA(F) \quad \propto \quad \log(Pr(X|F)) \quad \& \quad -c(F)$$

Where:

- $c(F)$ is the number of parameters of F (i.e. the degree of the polynomial F plus 1)
- F is supposed to be most accurately parameterised regarding X (i.e. it is the/a polynomial of degree $c(F) - 1$ that is closest to X in terms of the sum of squares of the differences).

Abductive rule:

Infer from data X that F_i such that F_i is best given the set of alternatives $F_1, \ldots, F_n$, i.e.:

$$EPA(F_i) > EPA(F_j) \quad \forall j \neq i : 1 \leq j \leq n$$

Meta-Abduction, Laws, and Realism

Meta-induction & weak optimality principle (*) justify WL-uniformity ("restricted uniformity").

Employing (meta-)abduction allows for a generalisation to SL-uniformity.

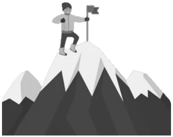
The strong optimality principle (**) gives us a realist interpretation.

Such an interpretation can sometimes be backed by epistemic considerations alone (predictive accuracy $\Rightarrow$ estimated predictive accuracy).

Conclusion

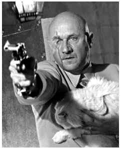
We have outlined two instances of epistemic engineering:

Meta-Induction as re-engineering the epistemic goal of justifying induction



$\Rightarrow$

Meta-Abduction for engineering methods for the goal of justifying laws of nature



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