An overview of some ontological challenges in engineering maintenance

LOA: Laboratory for Applied Ontology

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Plan of the presentation

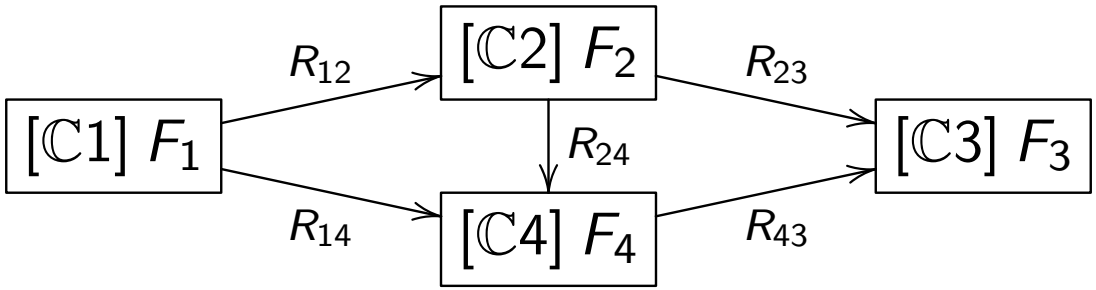
The replacement and the missing component problems

- **The replacement problem:** during maintenance, components of a plant or a machine are often replaced.
  A technician may say *"The right headlight of this car has been replaced twice"*.
  What has been replaced twice?

- **The missing component problem:** in an assembly line (or during a replacement) a technician may say *"The right headlight of this car has not been installed yet"*.
  What is not installed?

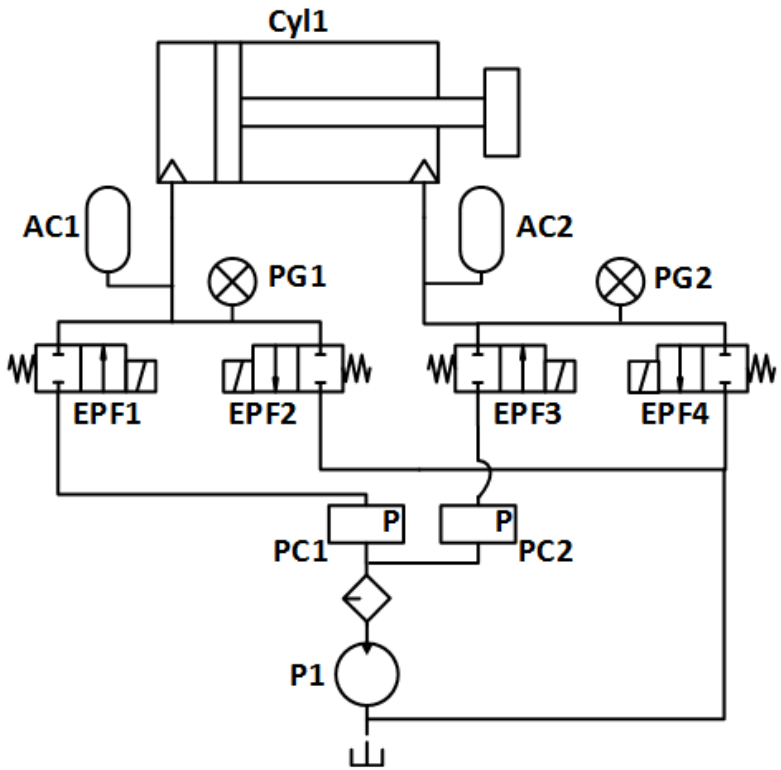
Four approaches: general framework

We want to speak about the *kind* of one or more systems. We assume that it can be described by means of the *features* of its components and of the *relations* between them.
One way to represent all this is with a graph:



Four approaches: general framework (tags)

After all, engineers already do so...



A hydraulic circuit diagram, taken from [4]

First approach: system-kinds as predicates

A standard approach consists in modelling a sistem-kind (say $\mathtt{K}$) in terms of first-order logic predicates. Additionally, this approach makes use of a three-dimentionalist perspective.

$$\begin{aligned}\mathtt{K}_t x \leftrightarrow \exists abcd(x \equiv_t a \oplus b \oplus c \oplus d \wedge \\ \mathtt{F1}_t a \wedge \mathtt{F2}_t b \wedge \mathtt{F3}_t c \wedge \mathtt{F4}_t d \wedge \\ \mathtt{R12}_t ab \wedge \mathtt{R14}_t ad \wedge \mathtt{R23}_t bc \wedge \mathtt{R43}_t dc \wedge \mathtt{R24}_t bd)\end{aligned}$$

In a similar way we can introduce predicates for the components $\mathtt{Ci}_t$

Four approaches: partial and full compliance

But what happens if one component is missing?

The previous definition implies that the individual system cannot be considered as of kind `K` anymore.

A solution is to weaken the specification of the kind `K`. That is, to consider *partial compliance*.

Second approach: reification

The second approach is conceptually similar to the first one, with a technical difference: the reification of the predicates. So that "$\mathtt{K}_t x$" becomes "$x ::_t \mathtt{k}$", where $\mathtt{k}$ is an individual constant representing the kind $\mathtt{K}$, and so on.

Reification let us to attach data to the predicates themselves.

$$x ::_t \mathtt{k} \leftrightarrow \exists abcd(x \equiv_t a \oplus b \oplus c \oplus d \wedge$$
$$a ::_t \mathtt{f1} \wedge b ::_t \mathtt{f2} \wedge c ::_t \mathtt{f3} \wedge d ::_t \mathtt{f2} \wedge$$
$$ab ::_t \mathtt{r12} \wedge \ldots)$$

Third approach: four-dimensionalism

Four-dimensionalism is the philosophical perspective according to which any given object we interact with is not a complete whole. It is just a *temporal slice* of a larger whole, extended in space and time alike (here we have mainly considered West [5, 2]).

If x is a 4D object, we write its temporal slice at time t as $x_{@t}$.

$$\mathtt{K}_t x \leftrightarrow \exists abcd(x_{@t} = a_{@t} \oplus b_{@t} \oplus c_{@t} \oplus d_{@t} \wedge \mathtt{F1} a_{@t} \wedge \ldots)$$

Comparison

First approach

- The replacement problem is paraphrased as e.g. *"Three different ordinary headlight served, at different times, as the right headlight of this car"*.
- If a component is missing there is nothing to refer to.

Second approach

- *"The right headlight of this car was made, at different times, of three different ordinary headlights"*.
- If a component is missing we can (superficially) refer to the reified predicate.

Third approach

- *"The 4D object that is the right headlight of this car has three different 'connected subsets'"*.
- If a component is missing there is nothing to refer to.

Fourth approach: embracing possibilism

- Inspired by Lewis' possibilist realism [3, 6]: a possible, *physical* object is just part of a maximally spatiotemporally related whole. Thus, design objects are physical, but not actual, objects.
- An actual physical object that is a duplicate of a design object is a realisation of the latter.
  But there are also actual *virtual projection* of design objects, that are intentional objects.
- If the component is missing we could refer to the virtual component, but then we would jump from a virtual to a real physical object, in a discontinuous way. A better solution could be, following Fine, to refer to a *variable embodiment* [1]

Conclusion and future work

Conclusion

We have compared the four approaches w.r.t. the missing component and the replacement problems.
When to use one or the other will depend on the modelling goals, the ontological commitment, and the specific use case.

(Possible) Future work

- Move towards a more complex models that could be implemented in real world scenarios.
- Further explore and formalize the fourth approach.
- Other possible lines of research are being investigated.

Bibliography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Thanks

Thanks!