Classification and Scientific Theories

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Classification and Science

- Background
- What we will (try to) show
- Classification
- How it might fit theory
- The Aircraft example
- Classification and Science
- Electromagnetism
- Summary

Background

- 30 years of working on the meaning of classification (with Jeff Parsons).
- We have assumed the use of cognitive views.
- Cognitive views require **efficiency** and **inference**.
  - Efficiency (economy): storage and retrieval efficiency.
  - Inference: infer some properties of an instance by it being a member of a class.
- Ideas applied to organization of data, than extended to conceptual models.
- The ideas had much more general interest, information is not unique to IT…
- We will describe our generalization to the **theories of science**.
- Is it useful? We hope to show this…

Brief summary

- Categorization is a very useful approach to organize facts around us.
  - Animals, planets,… whatever…
- Yet, at closer view, we assume a class should be more than a category:
  - A category that enables us to infer (derive) more facts about an instance.
  - Examples(s):
    - Consider: “things in my office” - a category. However, is it a class?
    - What if in my office – “nobody (except me) can do anything with it”.
    - And, if a category is not a class – do we learn anything from it?
- We have extended the ideas:
  - Formal definition.
  - Defined rules for collections of classes.
- And found it provided a way to think about how science progresses.

Classification ideas

Fundamental concepts:

- ***Phenomenon*** – anything of interest that can be described by factual statements (predicates).
  - Equivalently, we use the term ***instance***.
- ***Attribute*** – a predicate or statement that is true about a phenomenon.
  - We say the phenomenon ***possesses*** the attribute.
- ***Category*** – a set of attributes such that there exist phenomena that possess ***all*** the attributes in the set.
- ***Class*** – a category that can be partitioned into subsets of properties:
  - An instance possessing all attributes in the first subset.
  - Can derive: possesses all attributes in the second subset.

About classification

- Classification
  - Each class has instances.
    - There exists (in principle) at least one phenomena that possess all attributes defining the class.
  - Each class is defined in terms of **all attributes** common to all its instances.
  - Each class satisfies the condition:
    - At least one strict subset of its attributes (base) such that, if an instance, possess these attributes, it possesses the remaining attributes.
  - Each attribute of interest should appear in at least one class as a base or as an inferred attribute.
  - Why is this so useful?

An Example – Pluto (1)

Think about planets

- Old definition: round, “pretty large” and going around the sun.
- Is it a category, or a class?
- If we can say no more – then a category.
- What if we can say:
  - relatively planar (orbits in a plane).
  - and no orbit “touches” the orbit of another planet.
- These are inferences (Laws), and can be added to all.
  - Well, this was okay until Pluto was identified (1930).
  - When Pluto was discovered – it’s orbit did intersect Neptune, and, it was not “co-planer with other planets”.

An Example – Pluto (2)

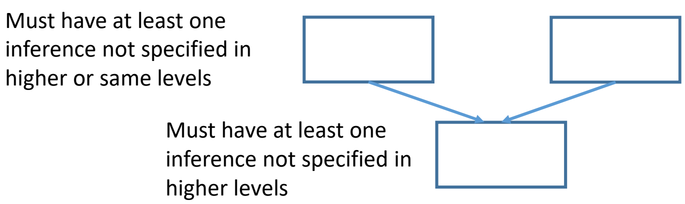
- In 2006 the International Astronomical Union (IAU) decided Pluto is not a “regular” planet… it is "dwarf planet“
- They decided that planets are:
  - (1) The object must be in orbit around the Sun.
  - (2) The object must be massive enough to be rounded by its own gravity.
  - (3) It must have cleared the neighborhood around its orbit.
- Pluto does not provide (3). So, it is a minor (dwarf) planet.
- However, if defining planets as “almost circular objects that are in orbit around the sun” – then it is a planet.
- So, it depends on what one wants “to do” with planets…

Wikipedia

Collection of classes

Three Conditions about forming a set of classes:

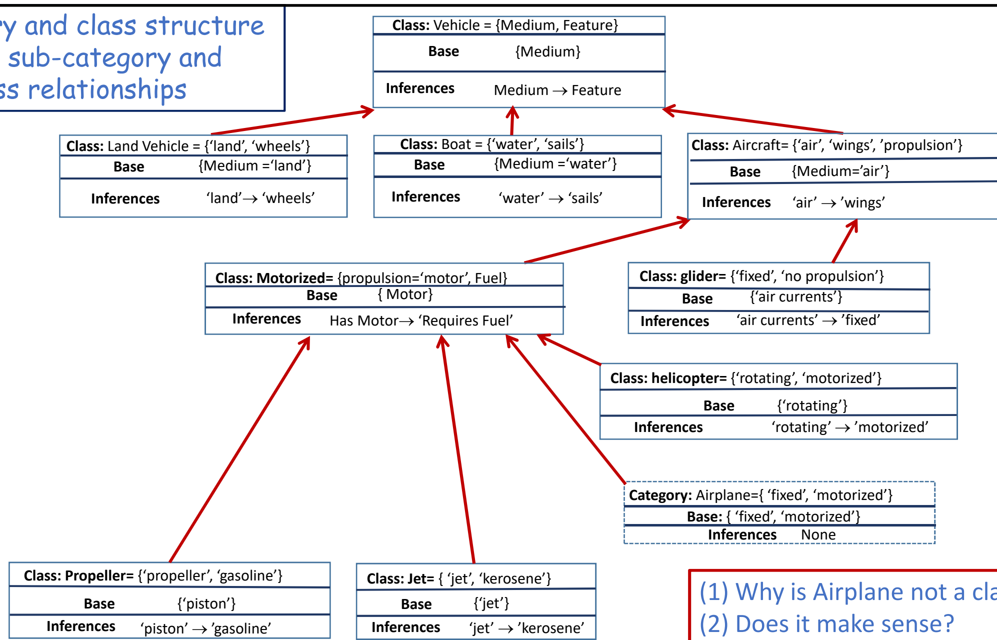
- If two classes have similar properties and inference, a higher level classes should be formed.
- Each class in a class structure should provide ***at least one*** inference not implied by any of its super-classes.
- A new class should be added to a class structure only if it provides inferences not provided by any existing classes in the structure.



The Aircraft case

- Let's assume we try to describe facts about Aircraft.
- We start with a diagram showing the main transport classes.
- Regarding aircraft - there are different types:
  - "regular" aircraft
  - helicopter
  - glider
- We will assume a new fact is found, and see how it can be "sorted out" into the class structure.
- We will then indicate the general rules that were applied.

Category and class structure to show sub-category and sub-class relationships



(1) Why is Airplane not a class?
(2) Does it make sense?
(3) What can be added?

What can we do?

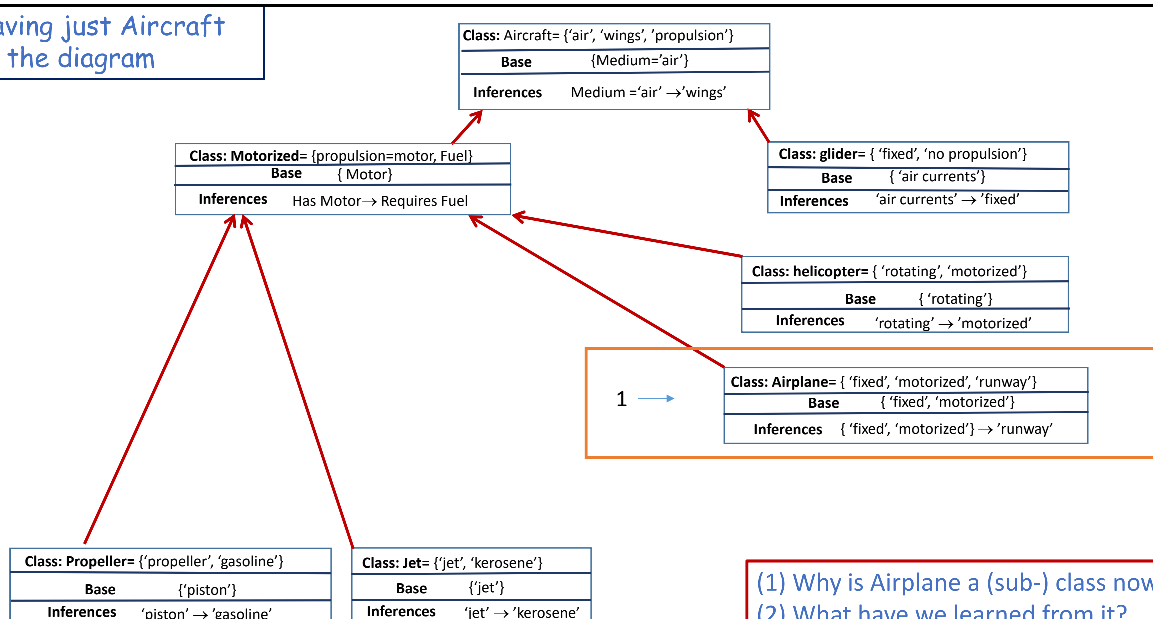
- The aircraft with "fixed wings" and "motorized" be a class (not a category only), if more properties are included:
- 'runway' can be included and it must appear in an inference.
- Two cases:
  - First, it can be an inferred property.
  - Second, it can be used (perhaps with other properties) to infer additional properties not inferred before.

About Aircrafts

- We uses Case 1: ‘runway’ is necessary to know the possible routes of an aircraft (it requires runways to depart and arrive).
  - If we add ‘routes include runways’, then can add the inference:
    {‘motorized’, ‘fixed wing’, ‘runway’} → ‘routes include runways’
    Makes the category a class.
  - Practically, this is useful for planning the possible routes for the aircraft.

Class: Airplane= { ‘fixed’, ‘motorized’, ‘runway’}	
Base	{ ‘fixed’, ‘motorized’}
Inferences	{ ‘fixed’, ‘motorized’} → ’runway’

Having just Aircraft on the diagram



(1) Why is Airplane a (sub-) class now?
(2) What have we learned from it?

What can we do in addition?

We have: {‘motorized’, ‘fixed wing’, ‘runway’} → ‘routes include runways’

- Similarly, we can create the class with the inference

  {‘motorized’, ‘fixed wing’, ‘water’} → ‘routes include body of water’
- Now, a (new) possibility arises. The two classes can be generalized:
  - Use the two properties (runway, water) to define the inference about *generalized take-off and landing*:
- The category:

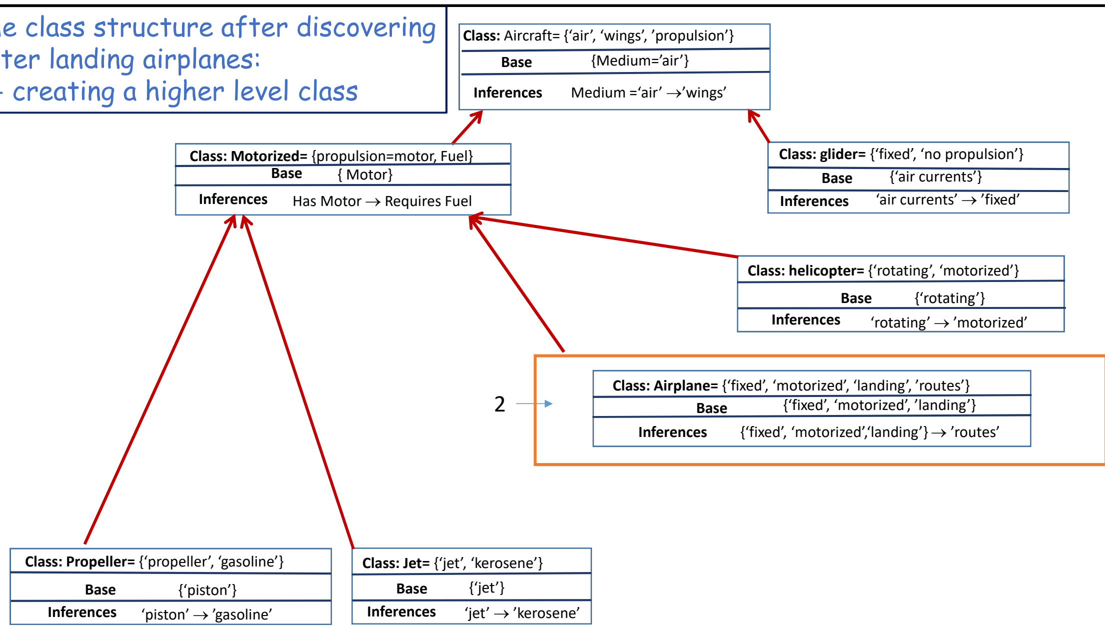
  Airplane = {‘fixed wing’, ‘motorized’, Facility, Routes}

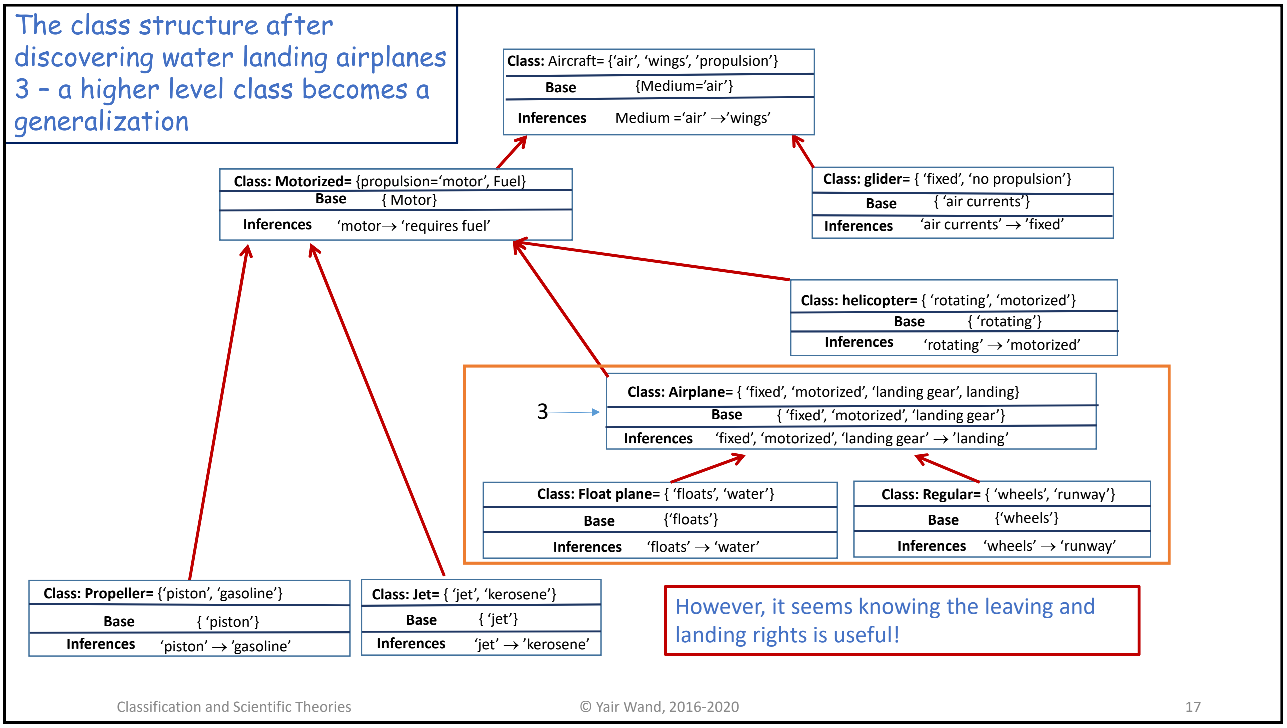
  with the inference

  {‘**fixed wing**’, ‘**motorized**’, Facility} → {Routes}

  is a superclass of the two new classes.

The class structure after discovering water landing airplanes: 2 - creating a higher level class





What have we learned?

Changing a class structure when cases contradicted by original observations		
Rule	**Principles**	**Rules/Guidelines**
If the inference cannot be justified	Remove the inference	If this inference made a class unique, it will be removed. This will result in [possible] loss of observed properties.
If the category seems "important"	Try to locate a sub-category of the original class (with the ability to infer or explain the "lost" property)	If a sub-category has an inference with the newly found property - it is then a class. Original property is defined with: {original, new found property, (maybe new property(ies))}
Try to identify inferences related to the contradiction	Case 1: "**Prediction**" of the new property **Original** (perhaps new properties) → **New Property** (the found one)	The new property is "predicted" by existing (and perhaps new) properties. (Prediction or explanation might "use" the original properties).
	Case 2: "**Explanation**" **Original** + **New Property** (the found one) → **New Property**	The additional property "explains" the "new" property. (Prediction or explanation might "use" the original properties).
Exploration: identify generalizations	If the correcting property covers all instances of the original class - we might be able to abstract the two ("new") subclasses generated into a higher level class.	The newly defined higher-level class replaces the original class. The additional found property are used to define or be explained in a more general way.

Classification and science (1)

- Scientific theories are about relationships of objects.
- The objects do not have to be "physical."
  - Example, in electromagnetic theory, it maybe about forces ("fields").
- Science begins with some observations.
- The observations are "summarized" in terms of categories.
- What makes science interesting – we know ***more*** about items then required to categorize them!

Classification and science (2)

- What makes science interesting – we know ***more*** about items then to categorize them!
- We know how to ***infer*** more properties.
- This knowledge is a "law" – relationship among attributes of a measured thing.
- Similar classes can sometime have a higher level class.
- **Claim**: If a category appears of interest – then there are laws(s) related to it.
  - otherwise, it is of no "real" interest

Example: Electromagnetism

Prior to Maxwell (late 1850) the following was known:

- Coulomb linked charges (Q) and electric forces (E): The relationship: L(Q,E).
- Conservation of charges. It links changes of charge (Q) and current (J). Shown by L(J,Q).
- No magnetic monopoles (B). The link is provided by the law L(B,0) - no monopoles exist.

"Newer" findings (at Maxwell's time) included:

- Faraday found a link between E and B: change of B can create electricity.
- Current can move magnets: found by Oersted - link between current and magnetic needle.
  - Ampere found the empirical law.
- Then, Maxwell added the "displacement" current: a ***change in time of electric field*** can generate magnetism.

Formulas

Knowledge at the beginning of 19th century

Class: {Charge, Force}
Law: L(E,Q)
Base: Q (distribution - ρ)
Name: Coulomb

Class: {Current, Charge}
Law: L(J,Q)
Base: J
Law: Conservation of Charge

Class: {B}
Law: L(B,0)
Base: B
No magnetic monopoles

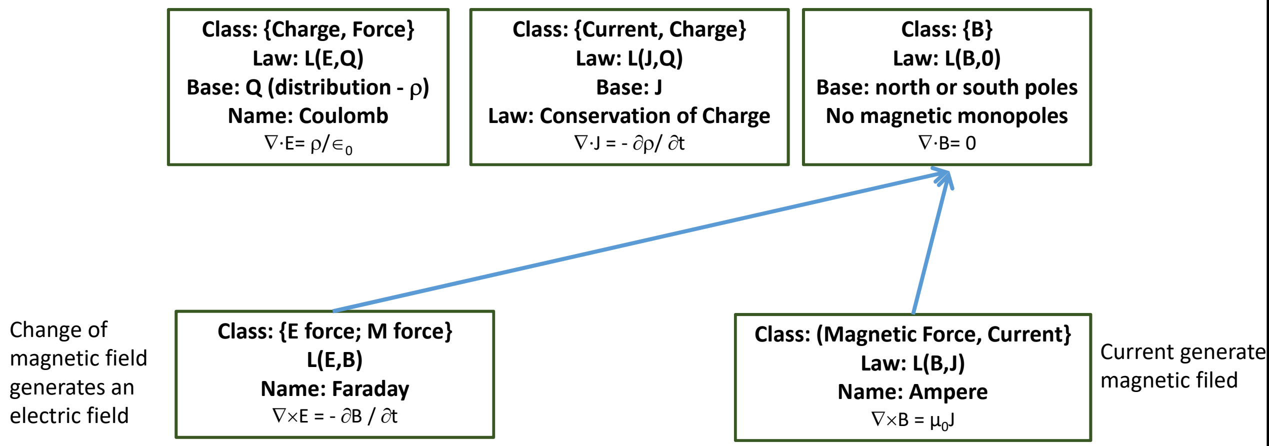
Same with some notation

Class: {Charge, Force}
Law: L(E,Q)
Base: Q (distribution - ρ)
Name: Coulomb
$\nabla \cdot E = \rho / \epsilon_0$

Class: {Current, Charge}
Law: L(J,Q)
Base: J
Law: Conservation of Charge
$\nabla \cdot J = -\partial \rho / \partial t$

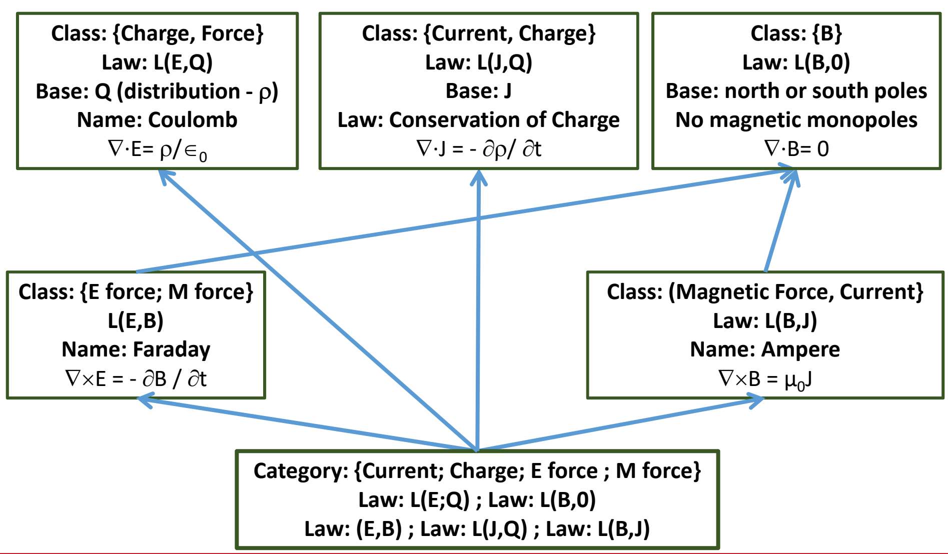
Class: {B}
Law: L(B,0)
Base: north or south pole
No magnetic monopoles
$\nabla \cdot B = 0$

Findings in the first three decades of the 19th century

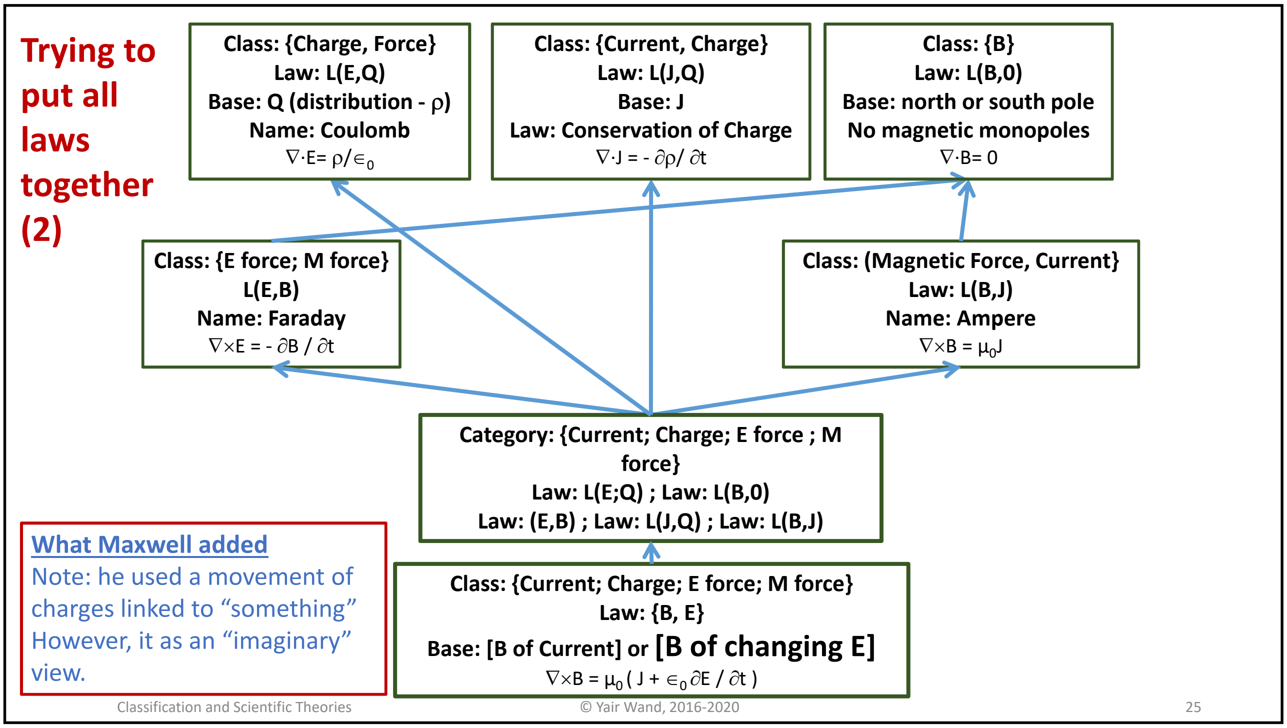


The category inherits all its laws from higher level classes but has additional laws of physics. Hence, they are all classes.

Trying to put all laws together (1)



The last category inherits all its laws from higher level classes.
It does not have a unique law to combined phenomena in an additional way.
It cannot be named a class.


Trying to put all laws together (2)
Class: {Charge, Force}
Law: L(E,Q)
Base: Q (distribution - ρ)
Name: Coulomb
∇·E= ρ/∈0
Class: {Current, Charge}
Law: L(J,Q)
Base: J
Law: Conservation of Charge
∇·J = - ∂ρ/ ∂t
Class: {B}
Law: L(B,0)
Base: north or south pole
No magnetic monopoles
∇·B= 0
Class: {E force; M force}
L(E,B)
Name: Faraday
∇×E = - ∂B / ∂t
Class: (Magnetic Force, Current}
Law: L(B,J)
Name: Ampere
∇×B = μ0J
Category: {Current; Charge; E force ; M force}
Law: L(E;Q) ; Law: L(B,0)
Law: (E,B) ; Law: L(J,Q) ; Law: L(B,J)
What Maxwell added
Note: he used a movement of charges linked to "something" However, it as an "imaginary" view.
Class: {Current; Charge; E force; M force}
Law: {B, E}
Base: [B of Current] or [B of changing E]
∇×B = μ0 (J + ∈0 ∂E / ∂t)
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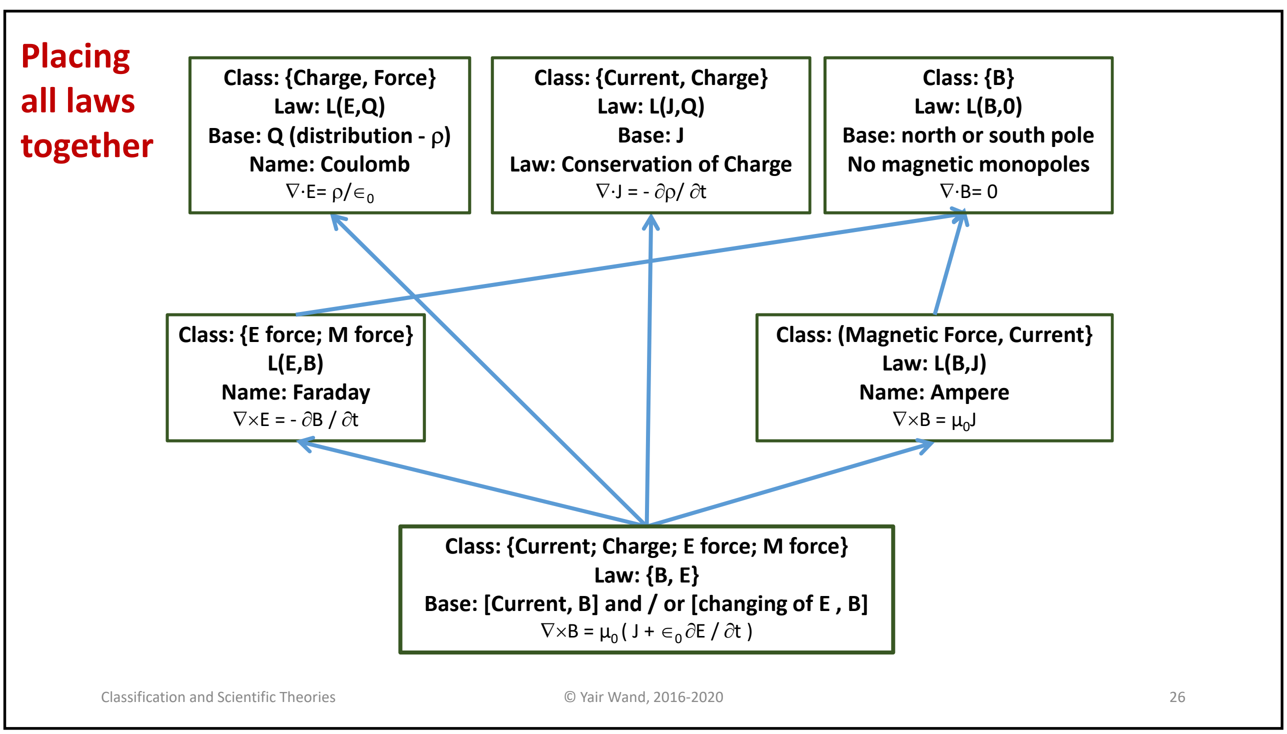
Placing all laws together
Class: {Charge, Force}
Law: L(E,Q)
Base: Q (distribution - ρ)
Name: Coulomb
∇·E= ρ/∈0
Class: {Current, Charge}
Law: L(J,Q)
Base: J
Law: Conservation of Charge
∇·J = - ∂ρ/ ∂t
Class: {B}
Law: L(B,0)
Base: north or south pole
No magnetic monopoles
∇·B= 0
Class: {E force; M force}
L(E,B)
Name: Faraday
∇×E = - ∂B / ∂t
Class: (Magnetic Force, Current}
Law: L(B,J)
Name: Ampere
∇×B = μ0J
Class: {Current; Charge; E force; M force}
Law: {B, E}
Base: [Current, B] and / or [changing of E , B]
∇×B = μ0 (J + ∈0 ∂E / ∂t)
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Result of Maxwell's addition

From Maxwell:

- Consider Base: [B of Current] and [B of changing E]
- Mathematically: $\nabla \times B = \mu_0 (J + \in_0 \partial E / \partial t)$
- **Changing E in time generated magnetic field.**
- $\in_0$ is permittivity (dielectric). μ_0 is permeability.
- Most interesting: $\mu_0 \times \in_0$ are experimentally known (in Maxwell time):
- **$\mu_0 \times \in_0 = 1 / c^2$**
- **Emergence of electromagnetism!**

Wikipedia

Summary (1)

- We made a distinction between categorization and classification.
- A class should provide ***more*** than a category.
  - Category is good for short (efficient) description.
  - For language.
- Classification means that there should be a ***reason*** for classifying.
- If there is no reason – than the category does not provide value.
  - Does not predict new attributes.
- What is a "law" – the inference – depends what we want ***to do*** with a class.

Summary (2)

- Applying this principle to science:
- We find that when a category is of value – there is a ***law*** to justify it.
- Higher level extraction – provides a higher level view of laws.
- Applying the inference value to the electromagnetic classification.
- It seems that it provides a way to think about how science progresses.

End

- **Questions?**
- **Comments?**

Yair Wand, Jeffrey Parsons, Alirio Rosales, “Scientific Theories as Classification Structures”, Working Paper, 2018-2020.

J. Parsons, Y. Wand, “Extending Classification Principles from Information Modeling to Other Disciplines”, *Journal of the Association for Information Systems*, Volume 14, Issue 5, May 2013, 245-273.

J. Parsons and Y. Wand, “Using Cognitive Principles to Guide Classification in Information Systems Modeling”, *MIS-Quarterly,* 32(4), December 2008, 839-868.

J. Parsons and Y. Wand, “A Question of Class”, *Nature*, Vol. 455, October 23, 2008, 1040-1041.

Wikipedia:
(Pluto 2020.09.29)

On September 13, 2006, the IAU included Pluto, and Eris and its moon Dysnomia, in their Minor Planet Catalogue, giving them the official minor planet designations "(134340) Pluto", "(136199) Eris", and "(136199) Eris I Dysnomia".[60] Had Pluto been included upon its discovery in 1930, it would have likely been designated 1164, following 1163 Saga, which was discovered a month earlier.[

Back

Wikipedia:

"In 1856 Rudolf Kohlrausch and Wilhelm Eduard Weber indicated that they "demonstrated that the **ratio of electrostatic to electromagnetic units** produced a number that matched the value of the then known **speed of light**. This finding led to Maxwell's conjecture that light is an electromagnetic wave. This also led to Weber's development of his theory of electrodynamics. Also, the first usage of the letter "c" to denote the speed of light was in an 1856 paper by Kohlrausch and Weber." (my highlights)

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And Science - Electromagnetism

Prior to Maxwell (late 1850) the following was known:

- Coulomb linked charges (Q) and electric forces (E): The relationship: L(Q,E).
  - which is also be shown by Laplace form: $\nabla \cdot E = \rho / \epsilon_0$
- Conservation of charges. It links changes of charge (Q) and current (J). Shown by L(J,Q).
  - Laplace: $\nabla \cdot J = - \partial\rho / \partial t$
- No magnetic monopoles (B). The link is provided by the law L(B,0) which means - no monopoles exist.
  - It can also be shown by Laplace form: $\nabla \cdot B = 0$

"Newer" findings (at Maxwell's time) included:

- Faraday found a link between E and B: change of B can create electricity.
  - $\nabla \times E = - \partial B / \partial t$
- Electric current can move magnets: First found by Oersted - a link between current and magnetic needle.
  - Ampere found the empirical law: L(B,J) which can be described by curl $\nabla \times B = \mu_0 J$.
- Then, Maxwell added the "displacement" current: a change of electric field can generate magnetism
  - $\nabla \times B = \mu_0 (J + \epsilon_0 \partial E / \partial t)$

Back Wikipedia

Wikipedia:
(2020.09.29)

Oliver Heaviside

In 1884 he recast Maxwell's mathematical analysis from its original cumbersome form (they had already been recast as quaternions) to its modern vector terminology, thereby reducing twelve of the original twenty equations in twenty unknowns down to the four differential equations in two unknowns we now know as Maxwell's equations. The four re-formulated Maxwell's equations describe the nature of electric charges (both static and moving), magnetic fields, and the relationship between the two, namely electromagnetic fields.

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