# Temporally Unique features

Goal: To find a feature that doesn’t change with time so that it can be used to identify an object at any point of it’s life.

Premise: We are dealing with human manufactured objects that are used in real world applications. In this use case, we have to be able to identify the object to track back to it’s manufacturer.

Features:
Material properties

Object:
Object for which features are being collected

Emergent features:
The feature or property which emerges due to another physical property of the material. For example, elasticity of a material is a physical property which is emerged from other physical properties like called inter molecular forces, molecular crystalline structure, shape and size of grains etc,.

Intrinsic property: The properties that are within the substance. These properties do not depend on the amount of material that you have. For example, density is an intrinsic property.

Extrinsic property: The properties that depend on the amount of the substance you have. All size measurements depend on amount, so all size measurements are extrinsic properties. For example, mass is an extrinsic property

Normally we identify things/objects based on their features. Features can be of any size or scale. Largest feature of any object being its size, weight, volume, color, surface texture, appearance, magnetic field reach (if the object has a magnetic field), thermal influence (if the object is not in thermal equilibrium with it’s surroundings) etc,. Any one of such features can be used by a person to differentiate the object from other objects. But most of the times using a single feature is not a robust way to identify an object uniquely, let alone in different times. So features have to a be as many as possible. **The combination of independent features will generate uniqueness to the object**.

For example, an object with feature ‘color red’ is not very unique to an object, an object with feature ‘color red, mass of 1kg, and sphere shaped’ is relatively more unique.

When talking about features that don’t change with time the loss of information from before time gap (manufacture year) and after time gap (failure year) should be acknowledged. The information we lost is the ‘influence of nature’ that the object has gone through during all these years. The influence of nature is dependent on the working environment of the object. The object can be a bolt which has been submerged in water and it has undergone corrosion. Another bolt of same standard has been utilized in a heavy industrial machinery and has undergone extreme shear loads and failed.


Any of the features of the bolt, that define it, may have been changed or lost or destroyed during it’s life time. But not all of it’s features are lost. The length of the bolt is virtually still the same. The weight of the bolt, density, thermal conductivity etc., are some of the features that are still unchanged for the above two bolts. The features that are influenced and features that are not influenced, vary depending on the application.
Important take away:

- Object that are defined by ‘more features’ are ‘more unique’.
- Depending on application, features of object that are unchanged, vary.

Assuming there is no way to extract the history of the object, we can only measure certain features or properties of the object before and after the time gap.
The manufacturer will not know the features that will stay unchanged after failure.
How to choose which feature to be measured?

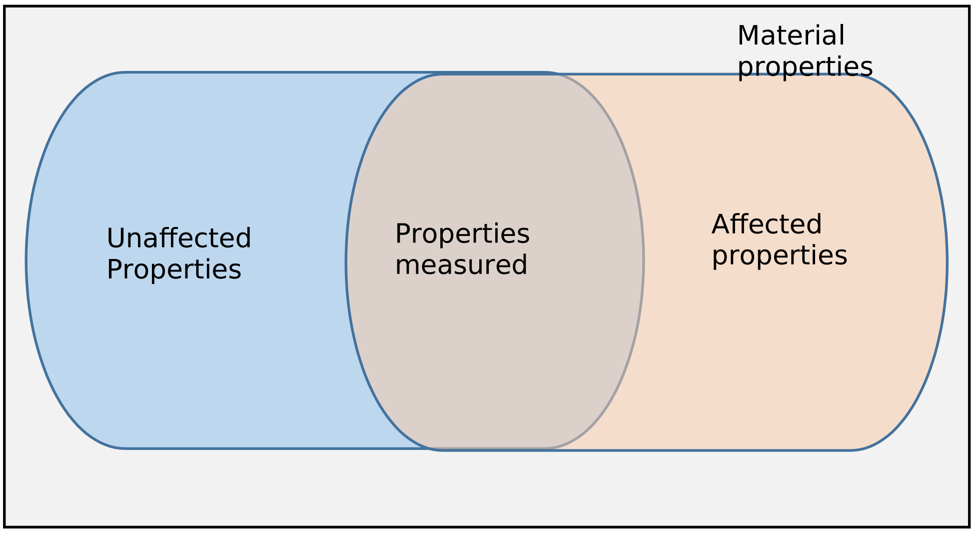
Nature of failure: The external influence on an object can be of microscopic or macroscopic scale. The scale that differentiates micro properties from macro properties is size.

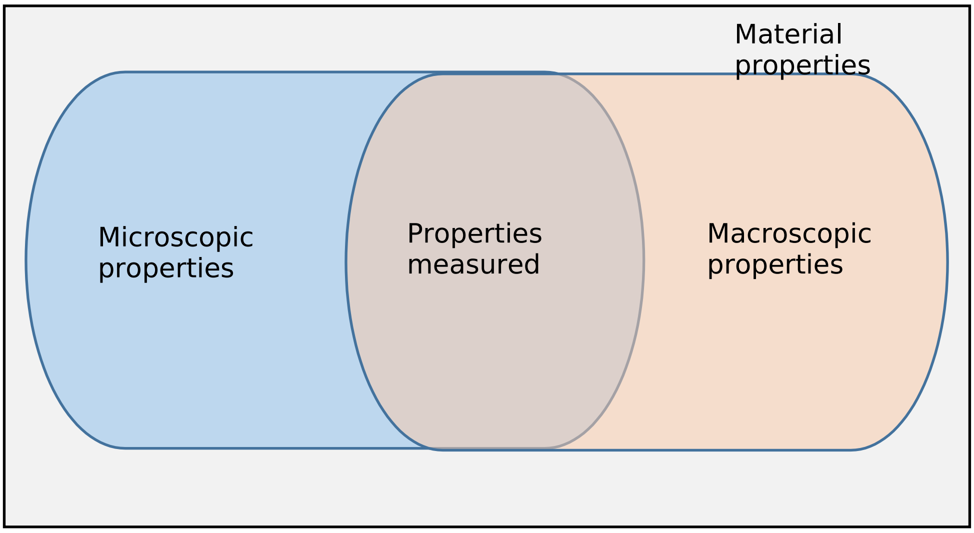
Micro properties: Crystalline structure, chemical composition of the material, number of free electrons, inter-molecular forces
Macro properties: ductility of material, electric, thermal and magnetic properties, melting point, hardness, flexibility etc.,

A failure can happen in any of the scale of the object. Large scale failure influence macroscopic properties of the object like shape, appearance, surface roughness can be influenced easily by nature.
**Assumption**: Properties like chemical composition, defect positions etc are highly unlikely to be influenced because such properties are shielded from the external influence.

Important take away:

- Microscopic properties of material are less likely to change, when compared to macroscopic properties.
- A feature set that will uniquely define an object should have following features:
  - Include both microscopic and macroscopic properties.
  - Include both affected and unaffected properties.




Non destructive Evaluation:
In the field of science and technology Non Destructive Testing (NDT) and Non Destructive Evaluation (NDE) are techniques used to measure the properties of a material without causing destruction to the test subject on any scale.

NDT techniques are widely accepted and a robust way to measure various kinds of properties of the material. NDT's are not made for generalized applications. They are extremely application oriented and most of the techniques are designed to be used only for specific applications like, weld quality evaluation, detection of surface and subsurface defects (different techniques for material with different porosity, conductivity etc.), internal defects, voids etc.,

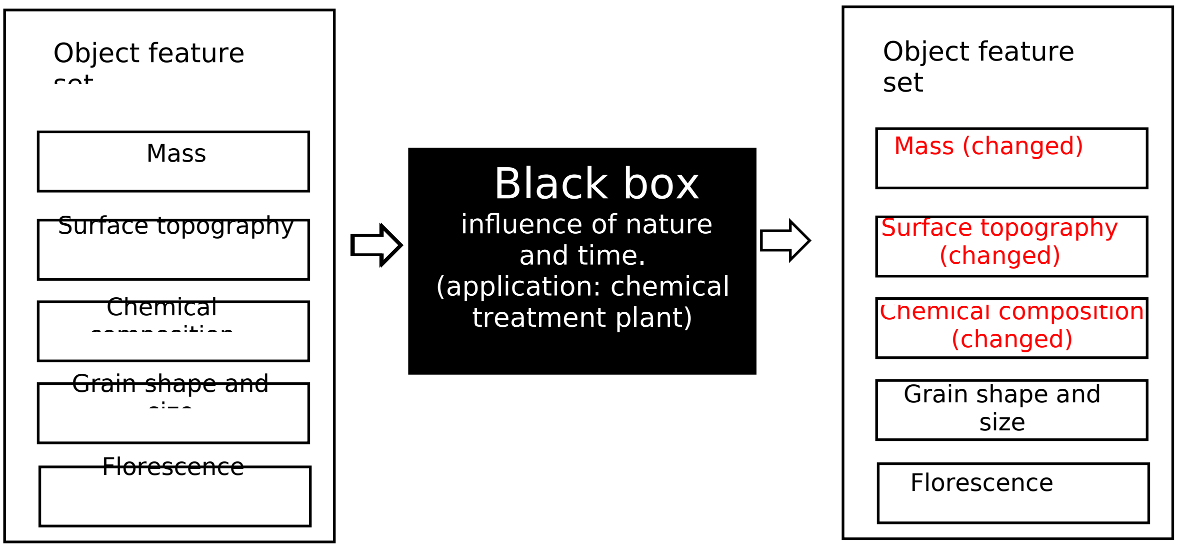
The document I have attached contains the list of NDT techniques, the property that each technique reveals, what are the factors that influence such properties and their typical industrial applications. The following image is a snapshot of the document.

| | how useful is it for our usecase |
|---|---|
| | low |
| | med |
| | high |
| | maybe |

| | output is | function of | typical applications | usecase |
|---|---|---|---|---|
| Scanning electron microscopy | magnified image of sub surfaces generated by electrons emitted from sub surface level of test subject. | surface roughness(topography), material of the test subject, ... | | |
| Ultrasonic testing (UT) | | | | |
| Acoustic resonance technology (ART) | resonant/natural frequencies of material | geometry, density, material, stiffness | unique fingerprint feature of components, detect cracks, voids, delaminations, lack of bonding and changes in hardness | |
| Electromagnetic acoustic transducer (EMAT) (non-contact) | resonant/natural frequencies of material | geometry, density, material, stiffness | material characterization, detect cracks, voids, delaminations, lack of bonding and changes in hardness | |
| Laser ultrasonics (LUT) | thickness of test object, surface defects | laser intensity, material thermal properties, material acoustic properties | composites, metals etc., materials that can withstand high temperatures. | |
| Phased array ultrasonics (PAUT) | surface and sub surface defects | beam angle, focal distance, material acoustic properties, defect position | weld inspection, thickness measurement, corrosion inspection | |
| Thickness measurement | | | | |
| Time of flight diffraction ultrasonics (TOFD) | signal about the cracks that originates by waves that difract around the crack. | defect characeteristics, angle of attack of US wave, material acoustic properties, geometry etc. | defects in welds, pipeline welds in particular. | |
| Time-of-flight ultrasonic determination of 3D elastic constants (TOF) | elastic properties of material | elastic properties of material | elastic properties of material | |

Approach 1:
We can define an object by it's intrinsic and extrinsic properties of all possible scales (microscopic properties and macroscopic properties).

Object(Magnetic field strength, geometry, mass, acoustic properties, surface texture, porosity, average grain size, molecular crystal configuration, etc.,) >>> Object(serial number, color, geometry)




The image above shows the influence of nature impacting two of the macroscopic features of the object and one microscopic feature , but the microscopic features are less likely to change. The feature that do change, are unique to environment of area of application.

Approach 2:

NDTs are used to check for defects which are surface level and subsurface level in most of the cases. Radiography techniques are used for detecting internal hidden defects, voids, cracks, failures etc., Most of the industrial application of NDT is mostly designed around the goal to find defects of all nature.

The nature of defects:
During the manufacturing process of any product/object, defects seep into the system are random but predictable to certain extent. Although some fabrication defects are absolutely unacceptable , most of the defects are acceptable if they are under certain predefined tolerance level. Hence defect tolerances are used to make sure that the usability of the product is not impacted. Tolerances are extremely application specific in nature.

The product that is inside the tolerance limit for all kinds of defects is ready for real world application and also it is not 100% defect free. **One can use the presence of such defects as a unique signature feature of the object**.

**Assumption**: Since defects are not human planned or designed, the defects that are under tolerance level are random and unique to object. Atleast certain percentage of such defects stay constant with time.

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