

UPDATING CRO TO CRO2

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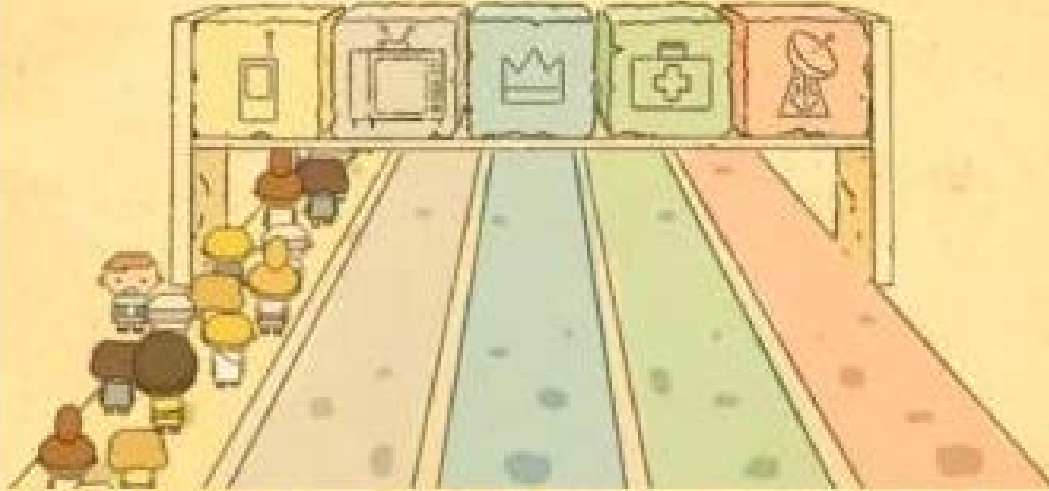
- ▶ Radio communication paradigm
- ▶ Uses Software Defined Radio (SDR) architecture
- ▶ Allows for dynamic change of a radio's operational behavior

Cognitive Radio (CR) is an adaptive, intelligent **radio** and network technology that can automatically detect available channels in a wireless spectrum and change transmission parameters enabling more communications to run concurrently and also improve **radio** operating behavior.

Cognitive radio (CR) is a form of wireless communication in which a transceiver can intelligently detect which communication channels are in use and which are not, and instantly move into vacant channels while avoiding occupied ones. This optimizes the use of available radio-frequency (RF) spectrum while minimizing interference to other users.

COGNITIVE RADIO (CR)

Mobile frequencies are getting crowded



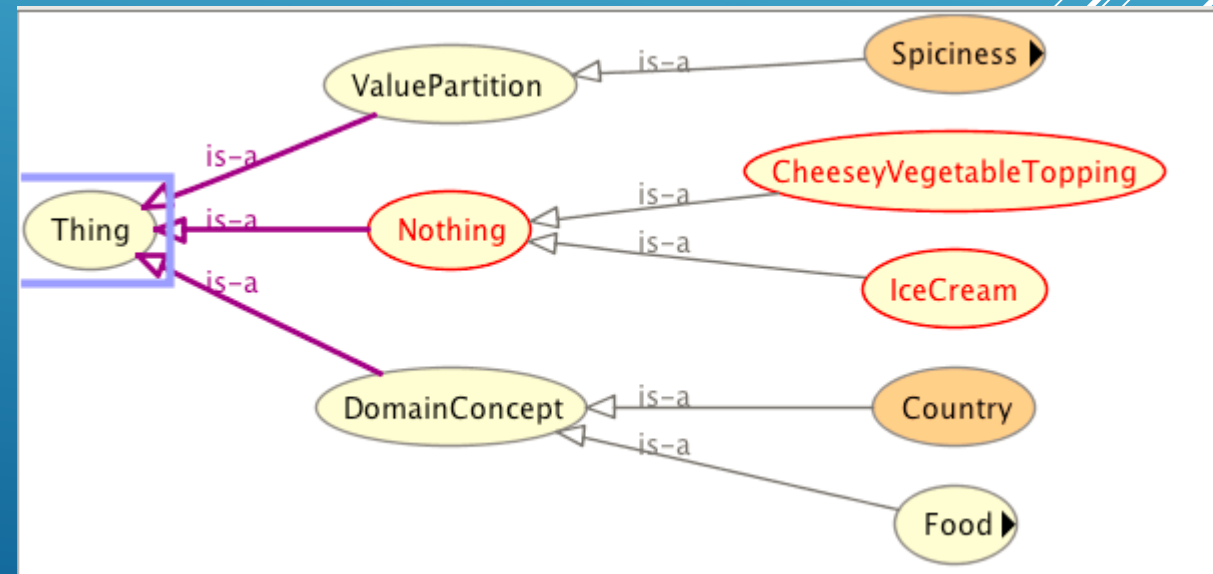
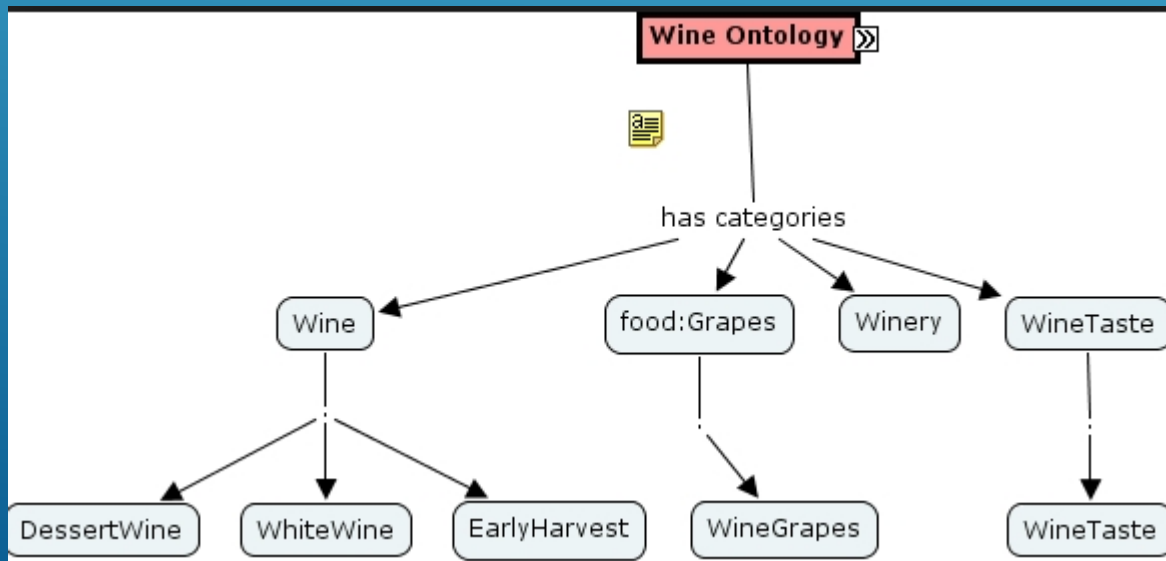
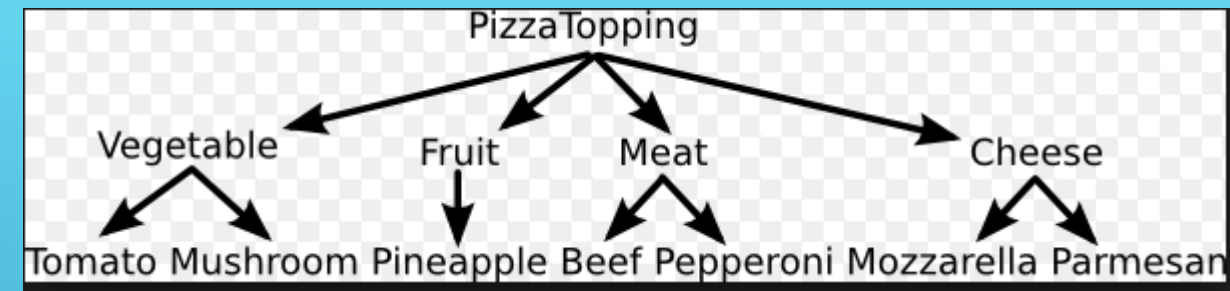
With Cognitive Radio you can use any channel



COGNITIVE RADIO

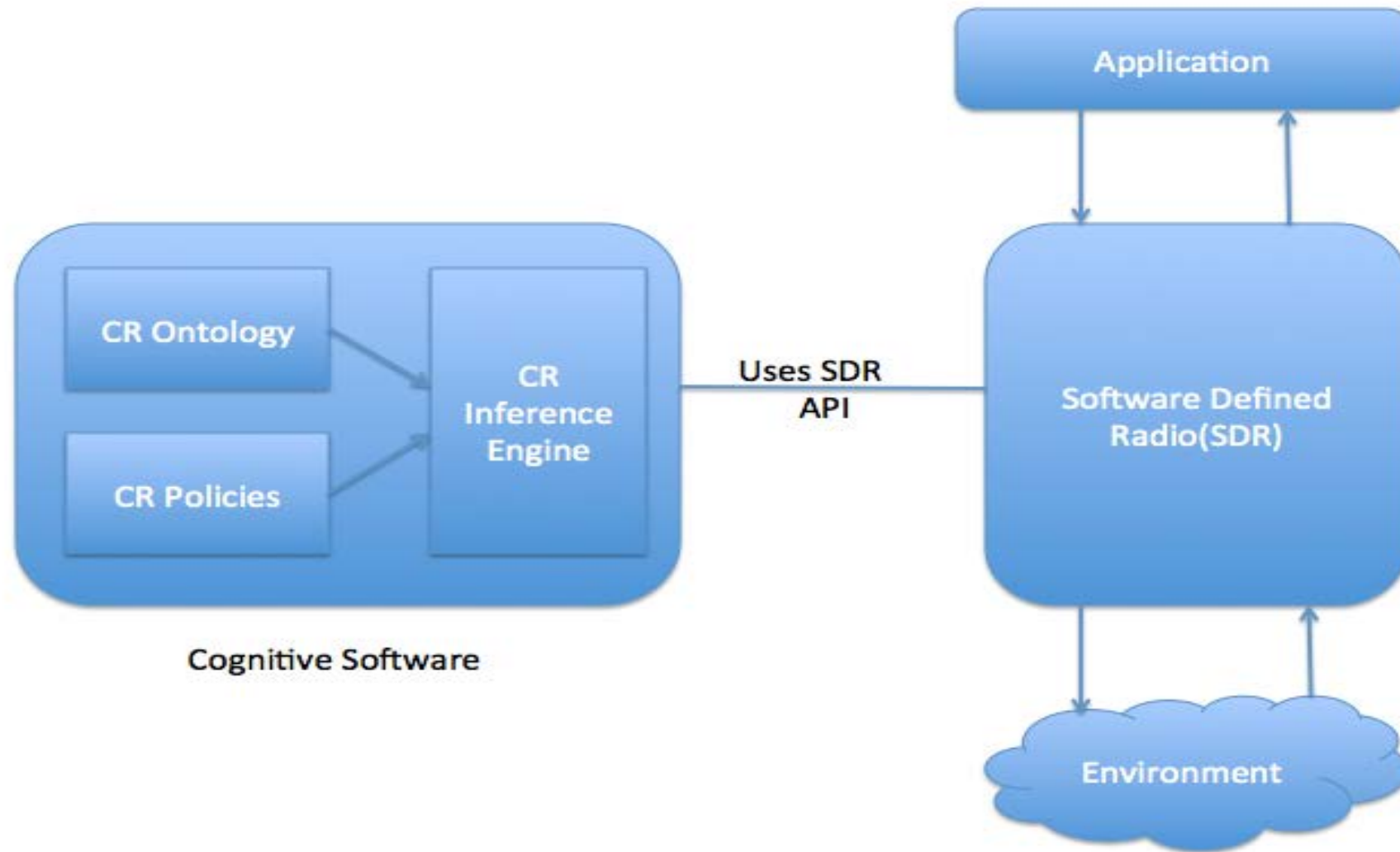
ONTOLOGY

- ▶ An ontology provides shared vocabulary about a specific domain
- ▶ Used to *model* knowledge
- ▶ Captures the types of objects that exist in the specific domain and the relations among them



- ▶ Developed by Modelling Language for Mobility (MLM) working group of the Wireless Innovation Forum (WIF)
- ▶ Patterned on Descriptive Ontology for Linguistics and Cognitive Engineering (DOLCE)
- ▶ The intent was establishing a common language for CR's to interoperate
- ▶ Covers the basic terms of wireless communication
- ▶ Partial representation of the FM3TR waveform
- ▶ Partial expression of the Transceiver API
- ▶ Tested on several use cases developed by MLM working group

COGNITIVE RADIO ONTOLOGY(CRO)



CRO IN THE REALM OF CR

- ▶ IEEE 1900.5 working group has incorporated CRO into their standard
- ▶ Spectrum Consumption Model (SCM)and SCM Markup Language (SCMML)
- ▶ DARPA sponsored DEV2WALDO
- ▶ Ontology-based waveform configurability
- ▶ Combining ontology with policy-based control for collaborative adaptation of Cognitive radio parameters
- ▶ Office of Naval Research (ONR) sponsored research project to develop Spectrum Knowledge Framework (SKF)

USES OF CRO

1. Modularity
2. Extensibility
3. Precision in defining classes
4. Compactness

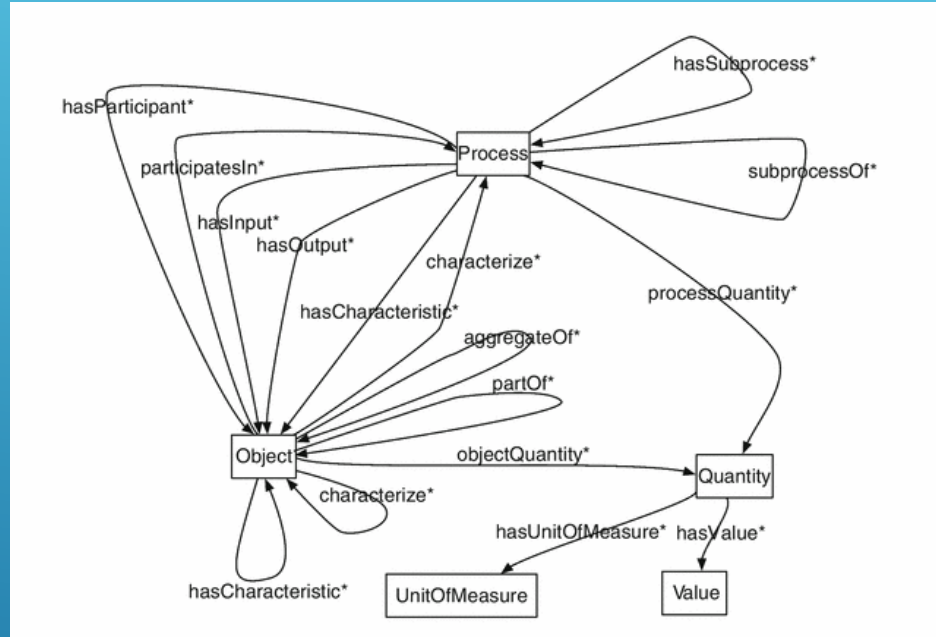
CRO EVALUATION – CAN CRO BE
IMPROVED? ARE THERE NEW
REQUIREMENTS?

- ▶ More modular design
- ▶ Extensible design
- ▶ Precision in Concept definition and support more Inference
- ▶ Compact design

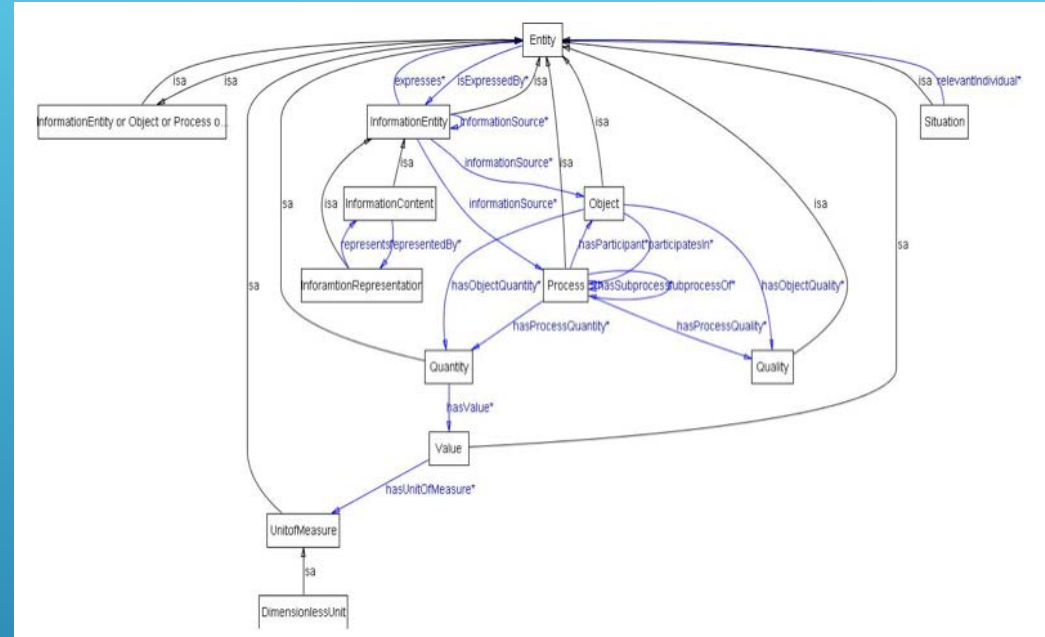
DESIRED SOLUTION

A series of white lines of varying lengths and orientations are positioned in the bottom right corner of the slide, creating a modern, abstract graphic element.

CRO



CRO2



COMPARING CRO TO CRO2

- ▶ Based on Nuvio (Northeastern and VISTology) foundational ontology
- ▶ Nuvio is inspired by the original CRO, QUDT (Quantity, Units, Dimensions and Types) ontology, DOLCE Ultra-Light ontology(DUL) and the Situation Theory ontology (STO-L)

CRO2

Modularization (in relation to software) as a mechanism for improving flexibility and comprehensibility of a system, the benefits of which were

- (1) shortening of development time,
- (2) flexibility to make changes to one module without changing the others and
- (3) being able to understand one module at a time

----- Parnas (1972)

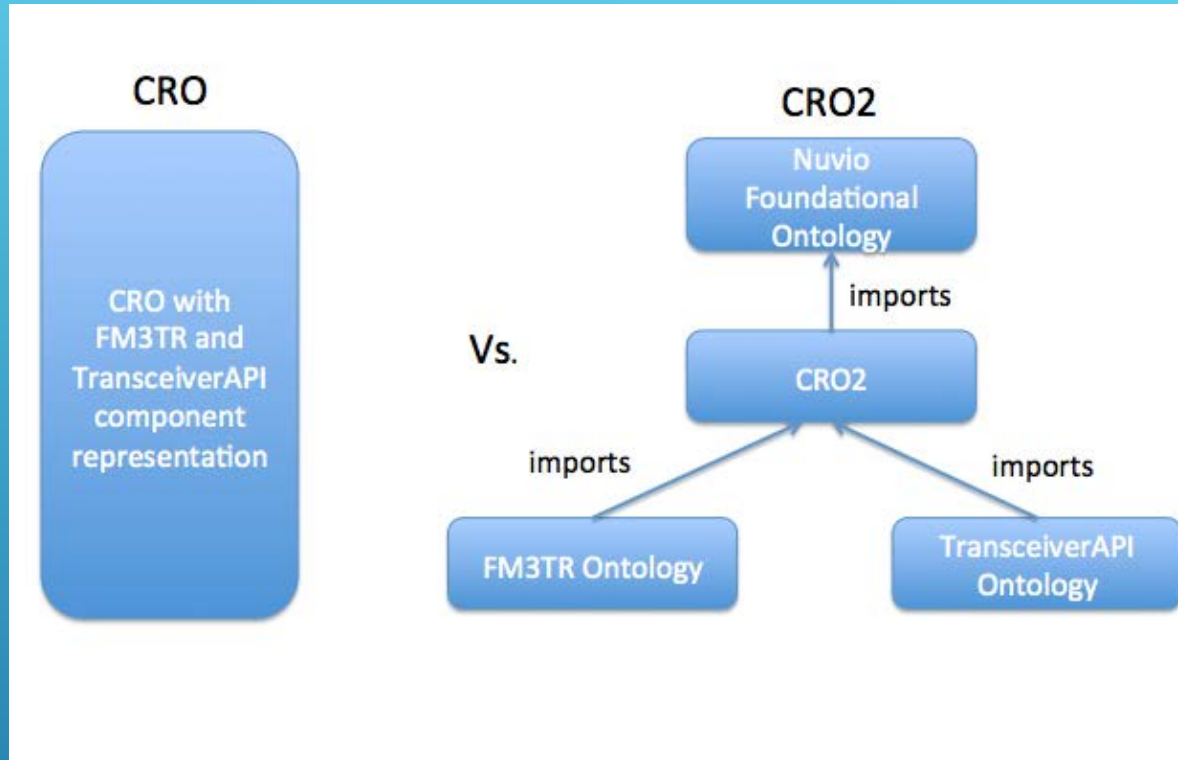
MODULAR DESIGN

- ▶ Decomposition is advantageous
- ▶ Can be measure using **cohesion** (the strength of the internal dependencies within a module) and **coupling** (a measure of the degree of dependency between modules)
- ▶ Good modular design is one with high cohesion of each of the modules and low coupling among them.

MODULAR DESIGN

- ▶ Design ontologies in a modular fashion
- ▶ Ensure that ontological modules have strong cross-concept relationships inside each of the modules
- ▶ Align ontological modules with conceptual partitions of domains

MODULARIZATION OF ONTOLOGIES



MODULAR DESIGN

- ▶ The features of an ontology that make it possible to extend this ontology in the future
- ▶ Not similar to reusability; new code is added that can connect with existing code

EXTENSIBILITY

- ▶ Any changes can be made to any of the existing system functionalities

and/or

- ▶ Addition of new functionalities can be done with, all with "minimum impact"

METRICS OF EXTENSIBILITY

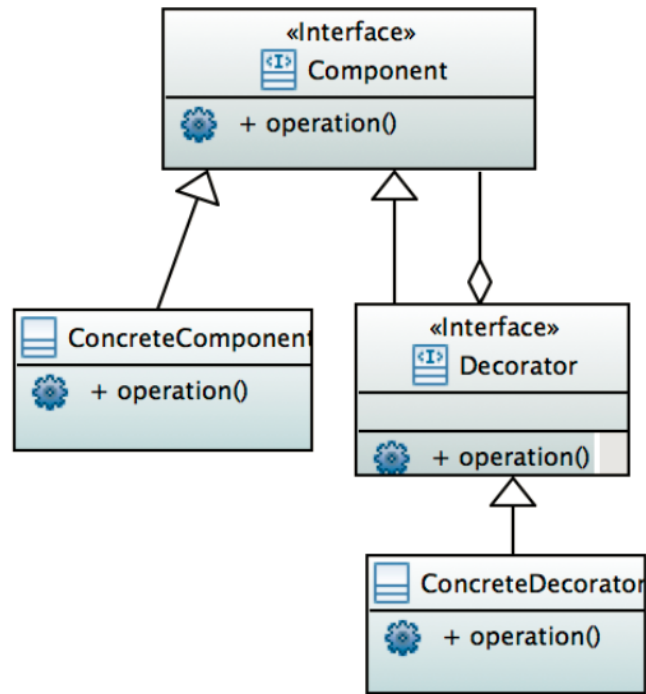
- ▶ **Design patterns** are solutions to software **design** problems you find again and again in real-world application development. **Patterns** are about reusable **designs** and interactions of objects.

---<http://www.dofactory.com/net/design-pattern>

- ▶ In software engineering, a **design pattern** is a general reusable solution to a commonly occurring problem within a given context in software design. A design pattern is not a finished design that can be transformed directly into source or machine code. It is a description or template for how to solve a problem that can be used in many different situations. Patterns are formalized best practices that the programmer can use to solve common problems when designing an application or system.

-- Wikipedia

DESIGN PATTERNS



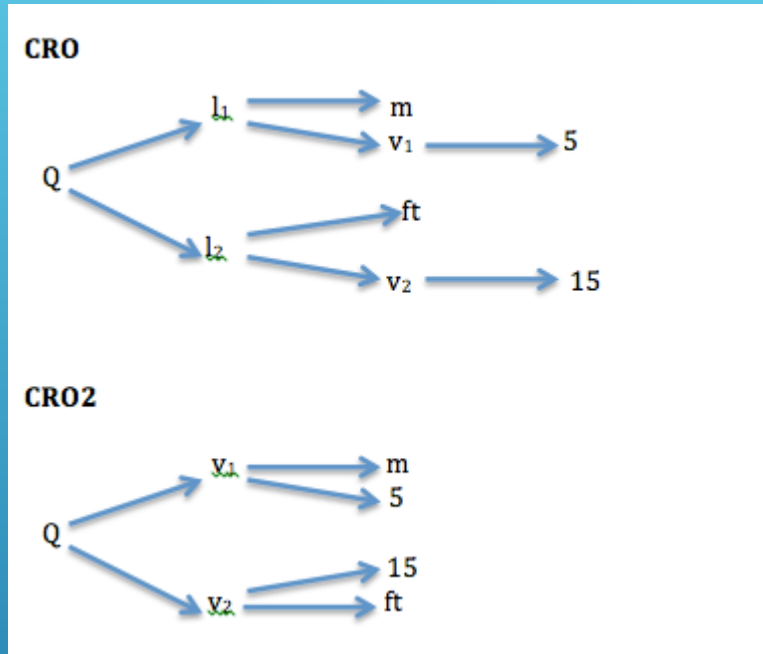
DECORATOR PATTERN

```
classDiagram
    class Object {
        +
    }
    class Thing {
        +
    }
    class val1 {
        +
    }
    class val2 {
        +
    }
    class Agent {
        +
    }
    class Goal {
        +
    }
    class G1 {
        +
    }
    Object --|> Thing
    Thing --|> val1
    val1 --|> val2
    Object --|> Agent
    Agent ..|> Goal
    Goal --|> G1
```

PRECISION

- ▶ Measure of size w.r.t size of domain knowledge that is covers
- ▶ Informal measure
- ▶ Quantitative comparison is possible
- ▶ Removal of FM3TR and Transceiver API as modules making CRO2 leaner

COMPACTNESS



QUANTITY, VALUE AND UNIT OF
MEASURE

228 classes,
190 properties
covering the basic terms of
wireless communications from the
PHY layer, MAC layer and network
layer.

169 classes
98 properties
covering all the terms that are
covered by the original CRO.

The major aspects of the development of CRO2 included:

1. A new foundational ontology (Nuvio) has been developed that is inspired by the original CRO, and other ontologies like QUDT, STO-L and DOLCE.
2. The representation of terms of the Transceiver API and FM3TR have been extracted to separate ontologies.
3. Quality features of ontologies have been analyzed and applied to CRO2.
4. The quality features have influenced the process of refactoring of the particular versions of the ontology.ng

SUMMARY OF CHANGES