Update and Pathway for UPR 1.0 Evolution

UPR: UML Profile for ROSETTA
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Background and Context

- **Purpose:** *introduce plans to evolve the UML profile for the modelling and simulation framework called ROSETTA*.*
- OMG discovered ROSETTA on MARS.
- UPR 1.0 is concerned with structuring information in support of model-based analysis for architecture optimization and *constraint driven system design.*
- In the development of the UML profile for ROSETTA [1] the question was asked at MARS: *can constraints also be logical?*

** ROSETTA: the Relational Oriented Systems Engineering Technology Trade-off and Analysis Framework [2, 3, 4, 5]*

Agenda

- Mathematical Basis of ROSETTA
  - Constraint driven design in UPR 1.0
  - Application to commercialisation of EV wireless charging
  - Concepts from UPR 1.0
- Relation to Kernel Modeling Language and Predicates
- Discussion of Pathway for UPR 1.0 Evolution

EV: Electric Vehicle

Constraint Driven Design (CDD) in UPR 1.0

UPR 1.0 facilitates the modelling of metric constraints for CDD [6]

- A *Variable* is a measurable attribute that represents an element being constrained and can take on a range of real values.
- A *Constraint* is a constant that limits the values of a variable.
- A *Comparison Operator*, such as '<', is used to model constraints.

A *Design Objective* is a measurable attribute of a system that the system is intended to have or achieve e.g., a requirement.

A *Design Variable* is a variable under the design authority of the engineer. It imparts system properties that achieve objectives e.g., a vehicle speed of > 100 mph can be achieved by reduced weight.

Application of UPR to Electric Vehicle(EV) Charging

Home - AMiCC - Amicable Charging Research Project (projectamicc.com)

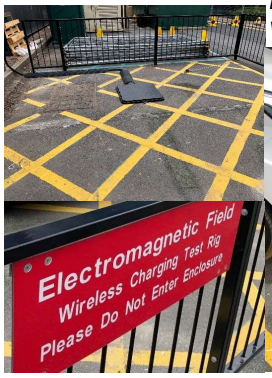
AMiCC is a commercialisation project for EV wireless charging supported by Innovate UK and funded by the Office for Zero Emission Vehicles (OZEV).

UPR facilities are being developed for metric constraints but are also needed for logical constraints (e.g., topologies).

Design objective constraints include
- Rate of power transfer
- Electromagnetic field strength

Design variable constraints include
- VA size and circuit topologies
- Cooling for power transfer
- Communication protocols

Ground assembly for WPT



EV retrofitted with VA, VIU and HMI for WPT

VA: Vehicle assembly GA: Ground assembly
WPT: Wireless power transfer
VIU: Vehicle interface unit
HMI: Human Machine Interface

Extensibility of UPR Facilities to WPT

- The emissions control example in UPR is extensible
  - Emissions → MFD emissions
  - The UPR facility is the same for both
  - Metric constraints are a class of design problems
- WPT has new design features for emission control
  - Coupling of induction coils
  - Circuit topologies are mixed metric and logical
- UPR 2.0 seeks software examples of logical constraints.
- Radar is a simple example of transmission/emissions.

WPT: Wireless power transfer
MFD: Magnetic flux density

ROSETTA Framework* for Modelling and Analysis

Radar System Example of Power Transfer

Key Radar Design Variables include:

- x_1 *: Transmitter power*
- x_2 *: Effective electronic area of aperture*
- x_3 *: Receiver sample rate*

Key Radar Design Objectives include:

- y_1 *: Transmitted power*
- y_2 *: Gain of aperture*
- y_3 *: Radar signal pulse width***

Dependencies:

Selection of pulse width depends on y_1 and y_2. These transform into sample rate dependencies on x_1 and x_2.

Target Model (Design Variables):

Source Model (Design Objectives):

				N			
						✓	x_1
						✓	x_2
							x_3

	y_1	y_2	y_3		x_1	x_2	x_3	
			✓	y_1	✓			
M			✓	y_2		✓		Q
				y_3			✓	

$(y_i, y_j) \in \boldsymbol{M}$ with $(y_i, x_k), (y_j, x_l) \in \mathbf{Q}$ implies $(x_k, x_l) \in \boldsymbol{N}$

***Pulse width could also be treated as a design variable but is given as a design objective because it determines frequency sidebands (emissions).*

**Refer to UPR 1.0 Figure 6-1 [6].*

Relational Orientation

Relational orientation as presented in [5] is a general systems methodology for system specification, analysis, and design that

- Employs a principle of *model specification and relational transformation* (an example being the ROSETTA framework on previous slide),
- Is similar to but more formal than the methodology of Klir [7], which rests upon a principle of alternatively using abstraction and interpretation, and
- Generalizes the functional and hierarchical viewpoint of legacy systems engineering, which rests upon a principle of *definition and decomposition* for system specification.

Relational Structure of Metric Constraints

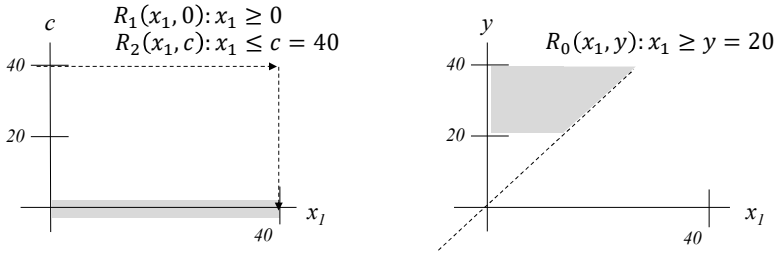
UPR [6] models mathematical-based constraints, referred to as *Mathematical Constraints*, using the following generic mathematical relation: 'a variable' is related to 'a value' by a 'comparison operator', where:

- A ***Variable*** represents the element being constrained. It can take on any real number when being unconstrained.
- A ***Comparison Operator***, such as '=' and '<', are mathematical symbols defined to indicate equality and inequalities.
- A ***Value*** is a real number. In UPR, it is unitless.

Predicates, Relations and Relational Structures

*Simplified radar example with metric constraints**

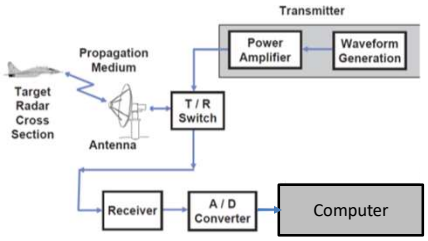
- The predicates $P_1(u_1, 0)$, $P_2(u_1, c)$ and $P_0(u_1, u_2)$ represent relations;
  - For example, the relations R_1, R_2 and R_0 where $u_1 \rightarrow x_1$, and $u_2 \rightarrow y$.
- The relations $\{R_0, R_1, R_2\}$ form a relational structure in the x_1y – plane
  - For example, $x_1 \leq 40$ is a relation in the x_1y – plane and $x_1 \leq y$ is another
  - The intersection is in the region above $y = x_1$ in Quadrant I
- The intersection is an *interpretation* of: $P_1(u_1, 0) \wedge P_2(u_1, c) \wedge P_0(u_1, u_2)$

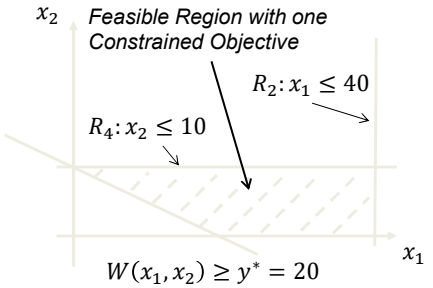


*Note: in this simplified design problem, $y = x_1 + 2x_2$ and x_2 has been set to zero.

Example of UPR model based analysis for system design:

Radar power aperture product (1 of 2)





Objective function:

$y = W(x_1, x_2) = x_1 + 2x_2$

Design Space:

$R_1: x_1 \geq 0$
$R_2: x_1 \leq 40\text{dBw} \quad (10\ \text{Kw})$
$R_3: x_2 \geq 0$
$R_4: x_2 \leq 10\text{dBsm} \quad (10\ \text{m}^2)$

Design problem:

Given a *Constraint* $y \geq y^*$ on the objective variable, *y*, determine all feasible (x_1, x_2) such that

$y^* \leq y = W(x_1, x_2)$

Example of UPR model based analysis for system design:

Radar power aperture product (2 of 2)

Objective function:

$y = W(x_1, x_2) = x_1 + 2x_2$

#	Applied Stereotype	Client	Supplier	polynomialCoefficient	polynomialBase
1	«» DOtoDVSensitivity [Dependency]	RX : Real	Power	1	0
2	«» DOtoDVSensitivity [Dependency]	RX : Real	Aperture	2	0

Design Space:

$R_1: x_1 \geq 0$
$R_2: x_1 \leq 40$ dBw
$R_3: x_2 \geq 0$
$R_4: x_2 \leq 10$ dBsm

Applied Stereotype	Name	Specification	Constrained Element	kind
«» DesignVariableConstraint [Constraint]	{ } P_TL	>=	Power Power = "0"	designRange
«» DesignVariableConstraint [Constraint]	{ } P_TU	<=	Power Power = "40"	designRange
«» DesignVariableConstraint [Constraint]	{ } A_eL	>=	Aperture Aperture = "0"	designRange
«» DesignVariableConstraint [Constraint]	{ } A_eU	<=	Aperture Aperture = "10"	designRange

Design problem:

Given a *Constraint* $y \geq y^*$ on the objective variable, *y*, determine all feasible (x_1, x_2) such that

$y^* \leq y = W(x_1, x_2)$

Applied Stereotype	Name	Specification	Constrained Element
«» DesignObjectiveConstraint [Constraint]	{ } P_RX	>=	RX : Real RX = 20.0

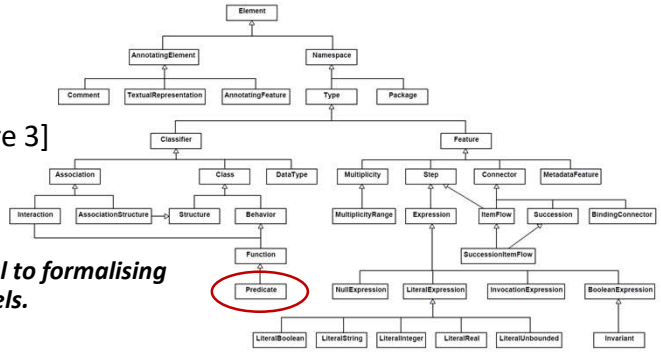
Agenda

- Mathematical Basis of ROSETTA
- *Relation to Kernel Modeling Language and Predicates*
  - KerML 1.0 Element Hierarchy
  - What is a Predicate?
  - The Predicate Calculus
- Discussion of Pathway for UPR 1.0 Evolution

KerML [8]

- [6.2 Document Conventions] Core mathematical semantics are generally expressed in terms of notations from first order logic.
- UPR 1.0 is mathematically based; and conforms to first order model theory in logic.

KerML Element Hierarchy [8, Figure 3]



Predicates are central to formalising object-oriented models.

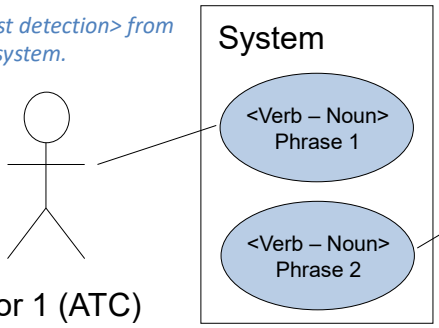
What is a Predicate? [9, 10]

Example of use cases for a radar system

Note that the System and <verb - noun> phrase always form a sentence.

ATC <request detection> from system.

System <detect aircraft>.



Actor 1 (ATC)

(e.g., subject of verb)

Actor 2 (Aircraft)

(e.g., object of verb)

A predicate is that part of a sentence containing a verb and stating something about the subject.

ATC: Air Traffic Control

What is the Predicate Calculus? [11]

- A formal language built from
  - Individual variables (denoted by lower case letters $u, v, \ldots$)
  - Symbols for constants (e.g., c)
  - Predicate letters (denoted by capital letters *P, Q,* …)
  - Logical connectives (*not* $\neg$, *and* $\wedge$, *or* $\vee$; also *equality* $=$)
  - Quantifiers: Universal, Existential
- Examples of predicate formulae:

$P(u_1, u_2)$; $Q(v, c)$; $P(u_1, u_2) \wedge Q(v, c)$; $\neg P(u_1, u_2) \vee Q(v, c)$

- Predicate letters are interpreted as relations.
- The Predicate Calculus formalises first order logic; validity depends on how predicates are assembled and interpreted. [Refer to the simplified radar example, slide 10.]

Agenda

- Mathematical Basis of ROSETTA
- Relation to Kernel Modeling Language and Predicates
- *Discussion of Pathway for UPR 1.0 Evolution*

Pathway for UPR 1.0 Evolution

- Scope of evolution is beyond UPR 1.0 RTF due to
  - Inclusion of logical constraints
  - Alignment of formal semantics with KerML/Predicates
  - Utilising SysML 2.0 for design analysis
  - Supporting CDD automation
- Therefore, UPR 2.0 seeks to
  - Collaborate with key stakeholders to formulate RFP
    Tentatively Dec 2021 – March 2022
  - A team to put forward a proposal
    Aiming for Dec 2022 for submission

References (1 of 2)

[1] Dickerson, C.E. and S. Ji, Mathsig/2015-09-01, Profiling a Software Architecture for the Relational Oriented Systems Engineering Technology Trade-off and Analysis Framework (ROSETTA) v4.3.

[2] Dickerson, C.E. and D. Mavris, "Relational Oriented Systems Engineering (ROSE): Preliminary report," in Proc. IEEE SoSE '11, Albuquerque, 2011.

[3] Dickerson, C.E., "A relational oriented approach to system of systems assessment of alternatives for data link interoperability," *IEEE Systems Journal*, 16 May 2013.

[4] Mavris, D., K. Griendling and C. Dickerson, "Relational-Oriented Systems Engineering and Technology Trade-off Analysis Framework," *AIAA Journal of Aircraft*, 28 August 2013.

[5] Dickerson, C.E., and D. Mavris, "A Brief History of Models and Model Based Systems Engineering and the Case for Relational Orientation," *IEEE Systems Journal*, vol. 7, no. 4, 2013.

[6] (OMG) Object Management Group 2019, *UML Profile for ROSETTA (UPR) Version 1.0*

[7] G. Klir, *Facets of Systems Science*, New York: Plenum Press, 1991.

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[9] Dickerson, Charles E. et al, 2021. "Architecture definition in complex system design using model theory." *IEEE Systems Journal* 15, no. 2: 1847 – 1860.

[10] Dickerson, C.E. and Siyuan Ji, *Essential Architecture and Principles of Systems Engineering*. Boca Raton Florida: CRC Press Auerbach Publication, September 2021.

[11] Bell, John and Alan Slomson, *Models and Ultraproducts*. Amsterdam: North Holland 1969

AMiCC

www.projectamicc.com

AMiCC (AMiCable Charging) is a commercialisation project for EV wireless charging that will demonstrate how wireless technology can unlock a range of the blockers to the market transitioning to electric vehicles and decarbonized cities

Funded by: Office for Zero Emission Vehicles

Supported by: UKRI Innovate UK

Project Partners: Loughborough University, WMG University of Warwick, 4th Dimension Technology, Sprint Power, University of Nottingham, Leeds City Council