Object Oriented Design in Energy & Decision Management

CalPlug 18th Workshop

October 18, 2021
Major Topics

- Control types
  - Open Loop Control
  - Closed Loop Control
    - PID Loops
    - False Promise of Simplifying PID Loops
  - Virtual Closed Loop Control
    - Context
    - Application

- Influence of Object Oriented Design
  - Energy Management
    - Extreme Tagging
  - Decision Management
    - Decision as a Class of Object
  - Speed to Decision: Object Workflow
  - CRSP-DM: Cross-Industry Standard Process for Data Mining
Open Loop Control

Set Point Parameter in Controller → Control Signal → Active Cooling Process → Output without Managed Bias

Closed Loop Control

Set Point Parameter in Controller → Control Signal → Active Cooling Process

Measuring Element (e.g. - PID Loop)

Output with Managed Bias → Yes

No
The PID Loop & Full Expression of Error

\[ P = \text{Proportional (amplitude)} \]
\[ I = \text{Integral (time)} \]
\[ D = \text{Derivative (rate or slope)} \]

The limit of the controller's output as error approaches zero is zero:

\[ \lim_{s \to 0} f(X) = 0 \]
PID Loops in Control Theory

The limit of the controller's output as error approaches zero is zero:

\[ \lim_{S \to Z} f(X) = 0 \]

Full Expression of Error (LaPlace Transform):

\[ L(s) = [K_p + (K_I/s) + (K_Dxs)] \]

PID Loop

- \( K_p \) = Proportional (amplitude)
- \( K_I/s \) = Integral (time)
- \( K_Dxs \) = Derivative (rate or slope)
- \( K \) = Gain
- \( S \) = complex frequency

Control Signal

Set Point Parameter in Controller

Active Cooling Process

Output with Managed Bias

Yes

No
The False Promise of Simplifying PID Loops

If I and D are set to zero in order to simplify the PID Loop, then there only P remains to express error, therefore this modification cannot achieve a full expression of error.

Limited Expression of Error:

\[ [K_p + 0 + 0] \]

\( K = \text{Gains} \)
Virtual Closed Loop Control

Set Point Parameter in Controller → Control Signal → Active Cooling Process → Output with Managed Bias

Zone Temperature Sensor input

EDGE DEVICE IN THE FIELD

ADVANCED SUPERVISORY CONTROL

Zone Temperature Set Point Bias Adjustment via Machine Learning

GATEWAY

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Contextualizing Virtual Closed Loop Control for Energy Management

The 3 V's: Volume, Velocity, Variety

Enterprise Energy Management

Building as a Battery

Adaptive Energy Management

Gateway Technology

Virtual Closed Loop control

Machine Learning

Energy Control Measures

Temperature
Humidity
Indoor Air Quality
Pressure
Light

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Object Oriented Design

The Four Pillars of OOD

- Encapsulation
- Polymorphism
- Abstraction
- Inheritance

Class
Object
Extreme Tagging

#temperature | #saTemp | #zone | #setpoint | #los_angeles | #california | #united_states | #zip_code | #geo_code | #ASHRAE_zone | #commandable | #range | #unreasonable | #reasonable | #comfort | #demand_response | #edison | #utility | #pressure_dependent | #pressure_independent | ...

Vendor & Standards compatibility:

→ #saTemp → Novar auxTemp
→ #saTemp → jciSA_T
→ #saTemp → haystack dischAirTemp
→ #saTemp → brick, Google

Attributes

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<th>Entity</th>
<th>Param 1</th>
<th>Param 2</th>
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Queue

Los Angeles Gateway
Point of Sale Gateway
Point of Sale Gateway

← Cloud

Gateway (THIS IS OUR SOURCE OF TRUTH) →

Status

* - subject to four hour validation period

-Queued
-Cmd ack
-Pending*
-Executed*
-Success*
-Deleted

Returned to Queue
Decision Management & Object Oriented Design

Decision Requirements

- Gathering
- Understanding
- Valuable Prediction Goals
- Viable Goals
- Analytically Predictable Behaviors

The Four Pillars of OOD

- Encapsulation
- Polymorphism
- Abstraction
- Inheritance

Class (or Decision)

Object (an instance of a Class...or Decision)

Source: Digital Decisioning by James Taylor, 2nd edition, 2019
Speed to Decision: Object Workflow

Objects may include but are not limited to:
- Alarms
- Analytic Signals
- Contacts from field sites
- Budget Variance

Persistence, Coincidence & Intensity

Object Workflow:
1. **Site is Offline**
   - Yes: Open W/O's
   - No: RTU not Heating or Cooling
     - Yes: If Zone +/- 2° to set point: dispatch
     - No: RTU is Offline
       - Yes: Poor Delta T
         - Yes: Add to watch list
         - No: Decline
       - No: Direct
         - Yes: Append or open W/O's
         - No: Indirect
           - Yes: Append to future W/O's
1. **Dispatch**

Speed to Decision: Object Workflow
CRSP-DM: Cross-Industry Standard Process for Data Mining

1. Business Understanding
   - Yes → Data Understanding
   - No → Deployment

2. Data Understanding
   - Yes → Data
   - No → Modeling

3. Data
   - Yes → Evaluation
   - No → Data Preparation

4. Data Preparation
   - Yes → Data
   - No → Modeling

5. Modeling
   - Yes → Data
   - No → Evaluation

6. Evaluation
   - Yes → Data Understanding
   - No → Deployment

7. Deployment
   - Yes → Business Understanding
   - No → Evaluation
Thank you

Contact Information

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Link to the original 2019 Virtual Closed Loop Control whitepaper