



CASE-BASED REASONING CONTROL OF BIOLOGICAL WASTE WATER TREATMENT INTENDED TO BIOGAS PRODUCTS

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MAIN TOPICS

- Introduction
- Biogas from wastewater products
- Control of wastewater treatment plants (WWTP)
- Case-Based Reasoning /CBR/ approach
- Application of CBR for supervisory control of WWTP
- Conclusions



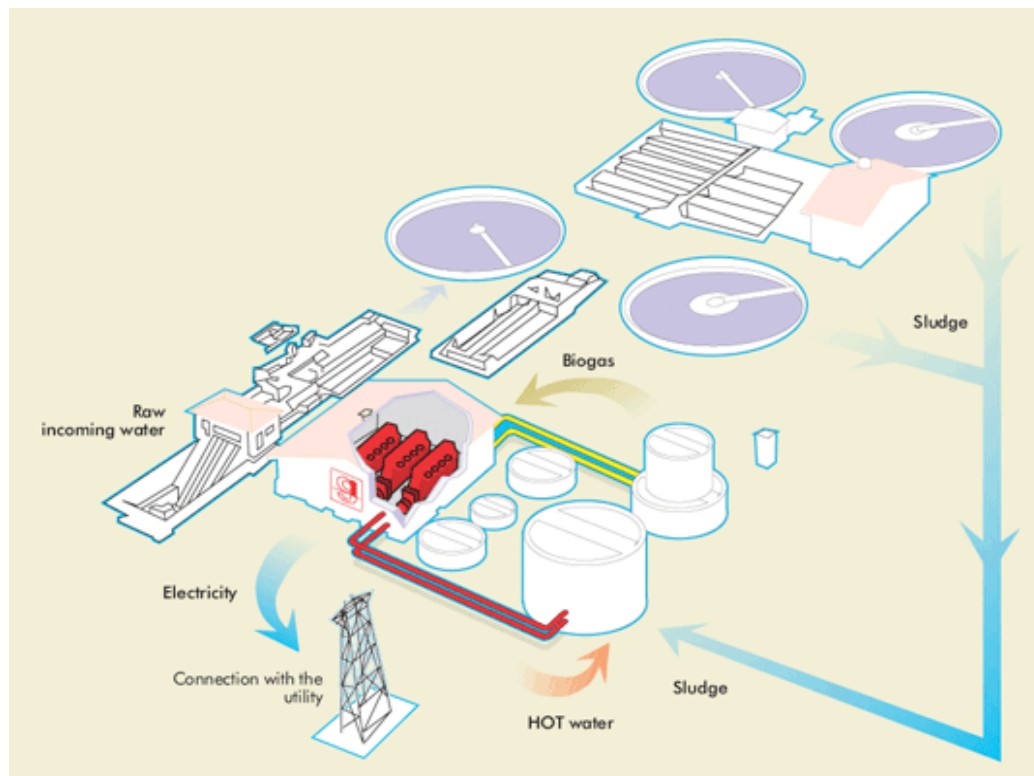
INTRODUCTION

- According to EU directives up to year 2020 in Bulgaria 16% of the energy must be produced by RES.
- The Co-generation installations using Biogas and sludge are of the promising potential sources.
- Supervisory control of wastewater facilities becomes of great importance, both for quality waste water cleaning and for sludge products used as sources for biogas.
- Current presentation describes the application of Case-Based Reasoning Supervisory Control of wastewater treatment plant.



BIOGAS FROM WASTEWATER PRODUCTS

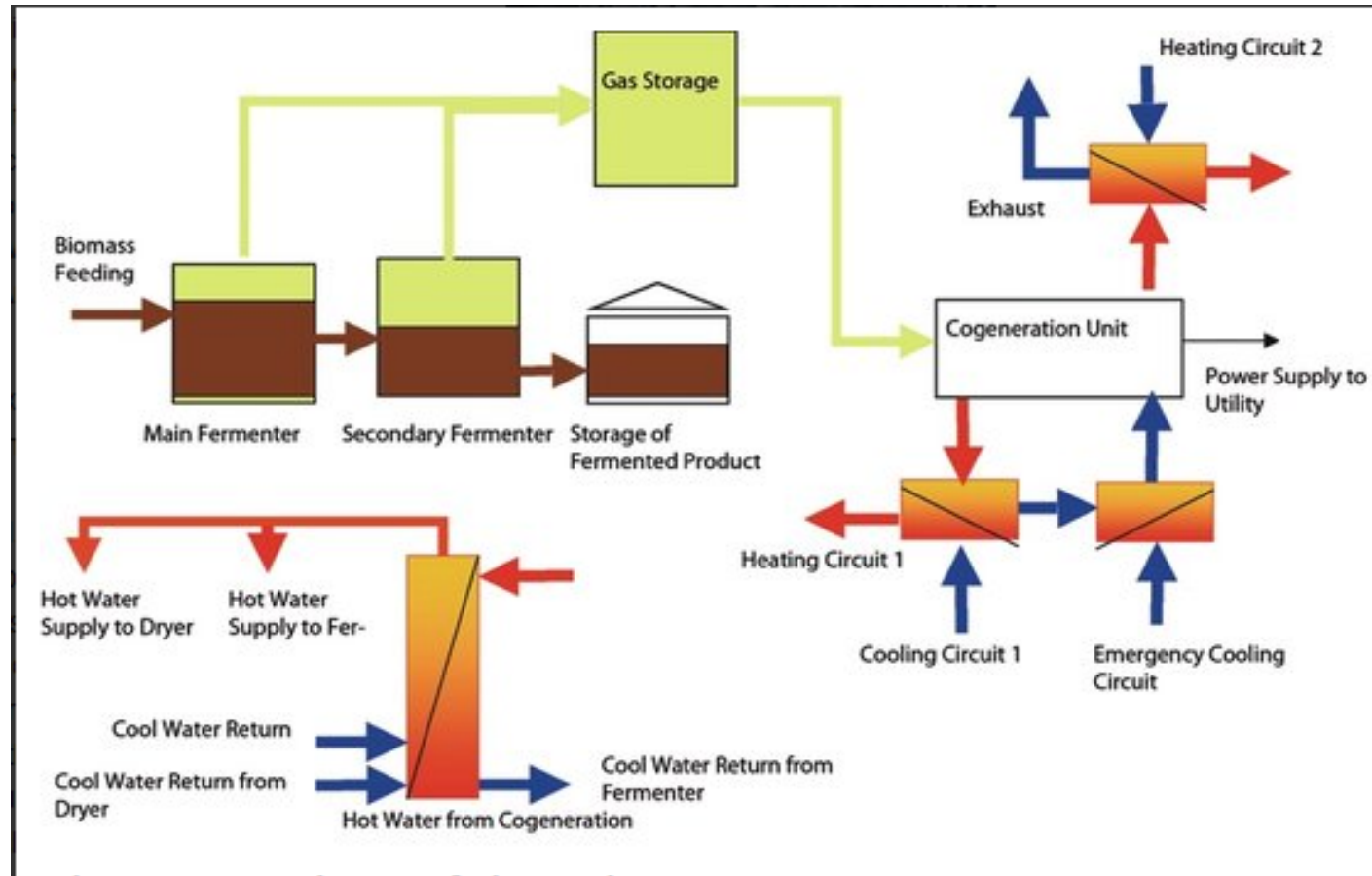
Stages of wastewater treatment



- Mechanical treatment
- Chemical treatment
- Biological treatment (anaerobic)
- Sludge treatment in fermenters
- Using biogas in Co-generation unit for electricity and hot water production

BIOGAS FROM WASTEWATER PRODUCTS AND BIOMASS

Stages of biomass treatment



BIOGAS FROM WASTEWATER PRODUCTS

TEDOM Co-generation Unit



- Technical data:
- Gas internal combustion engine with 6 cylinders.
- 160 kW electricity power
- 177 kW thermal power
- maximum gas consumption – 65 m³/h



CONTROL OF WWTP

- Problems that arise in the control of wastewater treatment plants (WWTP) are constantly subject to disturbances of different nature, namely
 - **external:**
 - resulting in changes in the debit and composition of the incoming water,
 - caused by the way of living and climate impacts,
 - and **internal:**
 - as operator errors,
 - technical errors,
 - and equipment failure.

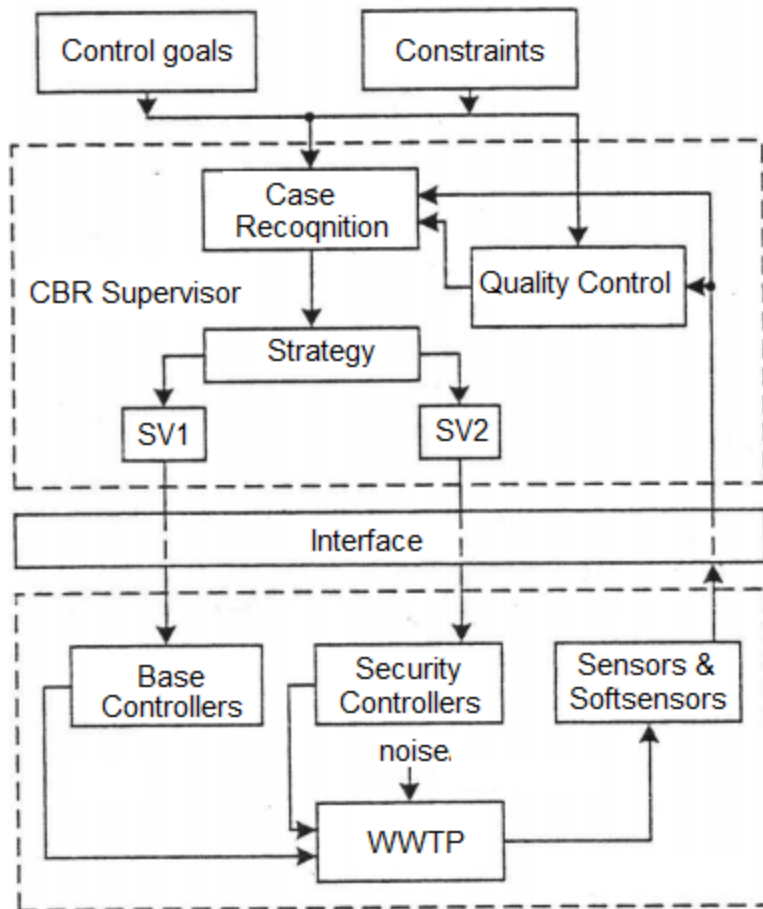


CONTROL OF WWTP

- Optimal control of WWTP requires for the particular condition of the disturbing inputs to minimize material and energy costs and maintenance, in compliance with legal requirements for the quality of the treated water.
- In supervisory process control the implementation of iterative procedures for finding optimal control is not recommended due to the possibility of falling into local extreme or uncertainty in terms of completion of iterative procedures.
- For the purposes of supervisory control of biological wastewater treatment in this work is proposed an approach based on precedents (Case-Based Reasoning (CBR))

CONTROL OF WWTP

CBR Supervisory Control

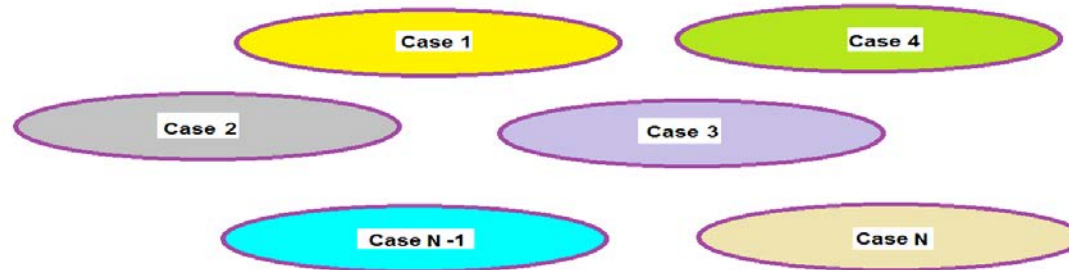


- High level (Goals and Constraints)
- CBR Supervisor Unit
- Interface
- WWTP with SCADA system including:
 - Sensors
 - Base Controllers
 - and Security Controllers



CASE-BASED REASONING (CBR)

The Basics of CBR

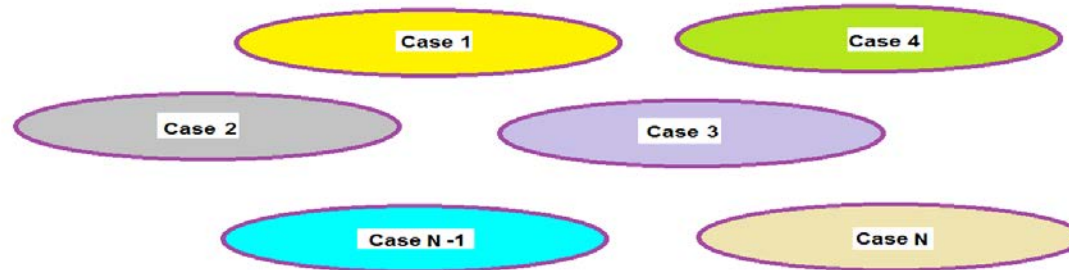


- The method of precedents (CBR) is a method of Artificial Intelligence.
- The basic idea of CBR is that "in similar situations we take similar decisions".
- In its classic form, it is a method of non-model control and is based on the accumulated expertise. It allows the presentation and retrieval of the best solutions for specific process control.



CASE-BASED REASONING

What are the CBR cases ?

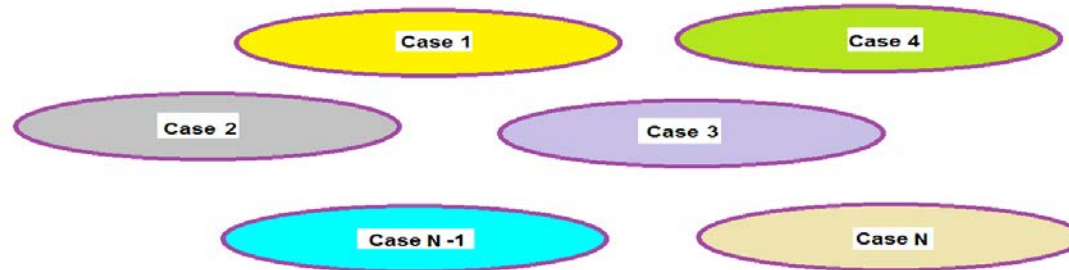


- Cases are the main object in CBR systems.
- They can be represented as free text or in structural type when the cases are represented as a parts of data base (case base).
- All structural cases are described as a pair of problem-solution. The problem $\mathbf{p}_i = (\mathbf{a}_i, \mathbf{v}_i)$ is a structure of attributes and values, described by the 2 vectors:
 - $\mathbf{a}_i = (\mathbf{a}_{i1}, \mathbf{a}_{i2}, \dots, \mathbf{a}_{ir})$ - attribute vector
 - $\mathbf{v}_i = (\mathbf{v}_{i1}, \mathbf{v}_{i2}, \dots, \mathbf{v}_{ir})$ - value vector.



CASE-BASED REASONING

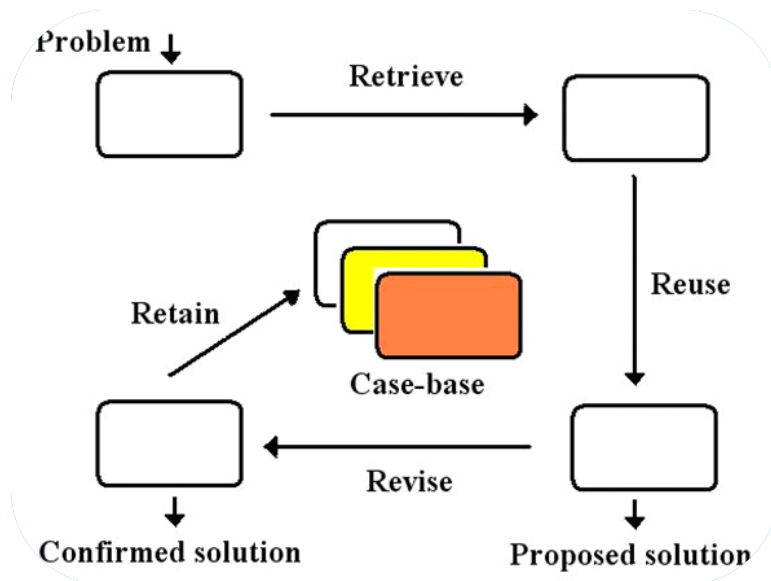
What are the CBR cases ?



- The solution s_i is represented as vectors, defined by the specific tasks. In multidimensional supervised control tasks, the decision includes two vectors:
- $s_i = (sp_i, pr_i)$, where the first vector
- $sp_i = (sp_{i1}, sp_{i2}, \dots, sp_{iq})$ consists of set-points of the controllers on first hierarchical level, and the second
- $pr_i = (pr_{i1}, pr_{i2}, \dots, pr_{im})$ – values of the target parameters, corresponding to the set-points.

CASE-BASED REASONING

Case-Based Reasoning Stages (CBR – R4 circle)

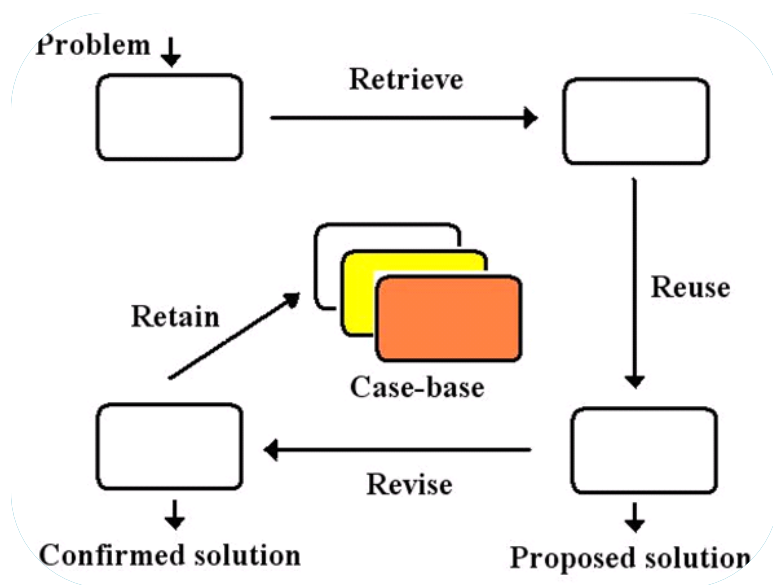


- **Retrieve** – process of extraction of one (nearest neighbor) or a group of cases (k-nearest neighbors) having closest definition to the current problem.
- The global similarity between the problems of these cases (the new \mathbf{p}_{new} and the one in the case base \mathbf{p}_j) is presented by following expression:

$$\text{sim}(\mathbf{p}_{\text{new}}, \mathbf{p}_j) = \sum_{i=1}^n w_i \text{sim}_i(\mathbf{p}_{\text{new}_i}, \mathbf{p}_{j_i}), \text{ and } \sum_{i=1}^n w_i = 1$$

CASE-BASED REASONING

Case-Based Reasoning Stages (CBR – R4 circle)



Where w_i is the weight of i -th attribute $0 \leq w_i \leq 1$

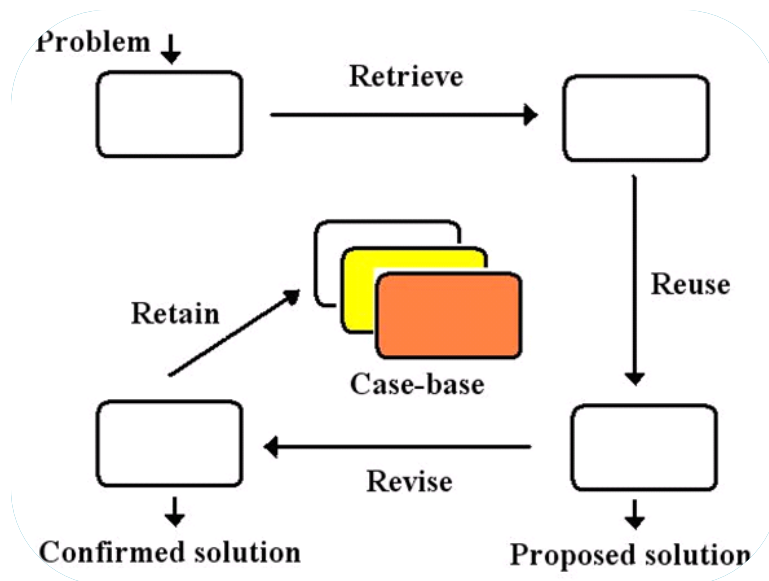
and $\text{sim}(p_{\text{new}i}, p_{ji})$ is the local similarity between i -th attributes in the case base DB.

$$\text{sim}(p_{\text{new}}, p_j) = \sum_{i=1}^n w_i \text{sim}_i(p_{\text{new}i}, p_{ji})$$

$$\sum_{i=1}^n w_i = 1$$

CASE-BASED REASONING

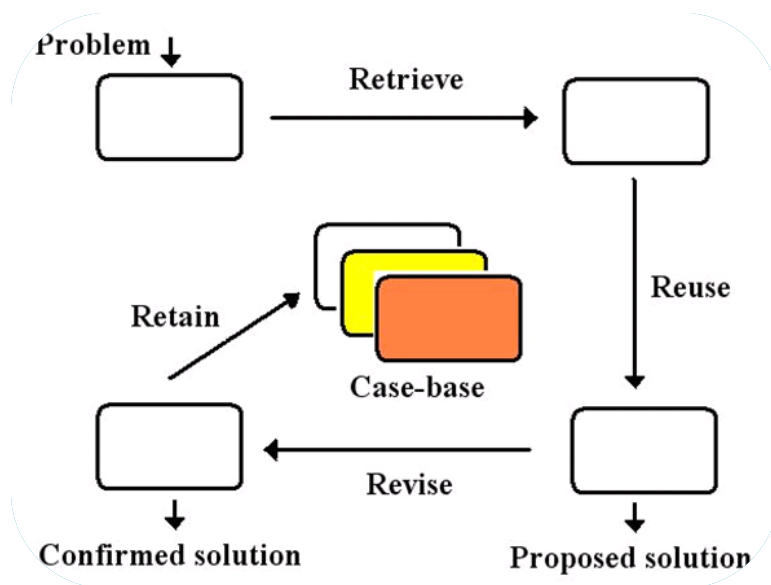
Case-Based Reasoning Stages (CBR – R4 circle)



- **Reuse** – reuse of the solutions of chosen in the first step one or k-nearest neighbors.
- - When only one nearest case is chosen, the solution of the new problem s_{new} will be the solution of the chosen case s_{NN} .
- - When k-nearest neighbors are chosen, the solution of the new case is calculated on the base of adaptation of k-nearest neighbors' solutions

CASE-BASED REASONING

Case-Based Reasoning Stages (CBR – R4 circle)

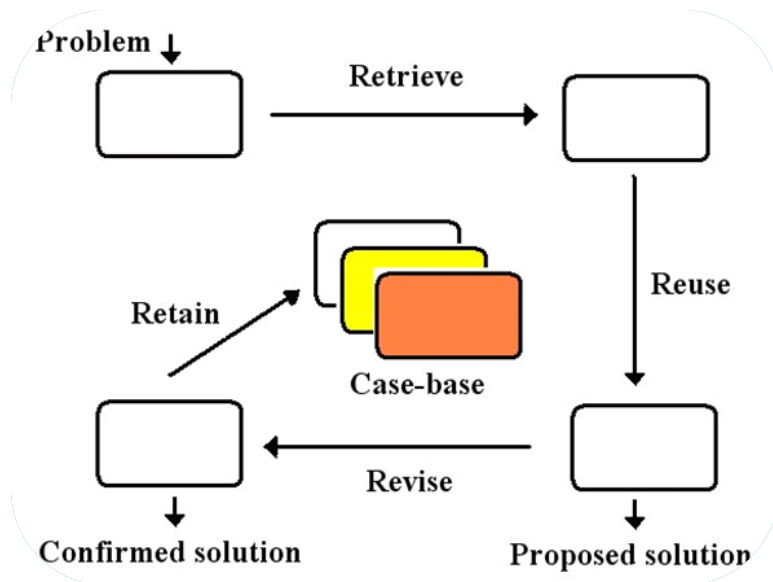


- **Revise** – decision propriety and utility verification, made on the Reuse stage.
- This verification is mostly done by an expert or it is made based on simulation researches if there is a mathematical model available.



CASE-BASED REASONING

Case-Based Reasoning Stages (CBR – R4 circle)



- **Retain** – saving (retaining) the new solution in the case base for future use, if it is successful.



APPLICATION OF CBR FOR SUPERVISORY CONTROL OF WWTP

Case structure in wastewater supervisory control

- Each case \mathbf{c}_i here can be presented as a structure of "problem-solution-forecast and economic efficiency“
- $\mathbf{c}_i = (\mathbf{p}_i, \mathbf{s}_i, \mathbf{pr}_i, \mathbf{ee}_i)$
- The problem $\mathbf{p}_i = (\mathbf{a}_i, \mathbf{v}_i)$ consists of attributes and values vectors, as given above.
- The solution $\mathbf{s}_i = (\mathbf{sp}_{i1}, \mathbf{sp}_{i2}, \dots, \mathbf{sp}_{iq})$ consists of set-points of the controllers on first hierarchical level, and the second
- $\mathbf{pr}_i = (\mathbf{pr}_{i1}, \mathbf{pr}_{i2}, \dots, \mathbf{pr}_{im})$ – values of the target parameters, corresponding to the set-points.
- Vector of indices characterizing the economic efficiency of the i -th case is denoted by $\mathbf{ee}_i = (\mathbf{ee}_{i1}, \mathbf{ee}_{i2}, \dots, \mathbf{ee}_{ip})$
-



APPLICATION OF CBR FOR SUPERVISORY CONTROL OF WWTP

Attributes describing the problem for the specific task

- The successful implementation of supervisory control setting is the ability to measure the concentrations of the most important components in the process of biological treatment. As attributes of the problem are selected variables that in modern WWTP are measured continuously.

$$\mathbf{a} = (Q_{in}, SNH_{in}, SNO(2), SNH(2), MLSS)$$

Q_{in} marked fuel inlet water purification,

SNH_{in} is the concentration of ammonia nitrogen in the incoming water, and its concentration is $SNH(2)$ output of denitrification,

$SNO(2)$ is the concentration of nitrate nitrogen output of nitrification and $MLSS$ is concentration of suspended solids in the tank floor.

APPLICATION OF CBR FOR SUPERVISORY CONTROL OF WWTP

Attributes describing the solutions (decisions)

- Decision are the set-points of controllers in the first hierarchy:

$$\mathbf{s} = (\text{DO}^0, Q_a, Q_r, Q_w, Q_{\text{carb}})$$

- DO^0 is the concentration of dissolved oxygen,
- Q_a is the internal recycle,
- Q_r is recycle of the activated sludge,
- Q_w is excessive sludge and
- Q_{carb} of external carbon.




APPLICATION OF CBR FOR SUPERVISORY CONTROL OF WWTP

Target variables

- Target variables in the treated water that match attribute values and assignments to regulators and is expected to be achieved by appropriate control are:

$$\mathbf{pr} = (\text{COD}_e, \text{BOD}_e, \text{TN}_e, \text{SNO}_e, \text{SNH}_e, \text{HRT}, \text{SRT})$$

Variables with index “e” refer to the composition of the treated water at the outlet of the WWTP, namely: **COD_e** is chemical oxygen demand, **BOD_e** is biological oxygen demand, **TN_e** is the concentration of total nitrogen, **SNO_e** - of nitrate and nitrite nitrogen and **SNH_e** ammonium nitrogen. **HRT** and **SRT** are the times to stay relevant in the biological stage of water and sludge.



APPLICATION OF CBR FOR SUPERVISORY CONTROL OF WWTP

Indicators of economic performance

- Indicators of economic performance are:
- $E_e = (EQ, z)$
- $EQ = E_{aer} / Q_{in}$ is the energy consumption for aeration E_{aer} relative to the cost of wastewater treatment Q_{in}
- z is an expert assessment of the costs of chemicals, which varies in the range $0 \leq z \leq 1$.



APPLICATION OF CBR FOR SUPERVISORY CONTROL OF WWTP

Generation of Case Base with optimal cases

1. To generate the initial DB with optimal precedent the following procedure was developed:
 1. Mathematical model of biological treatment, including a description of the processes in the bioreactor according to mathematical models ASMs and in the secondary clarifier is adapted to the specific WWTPs sizes and parameters in the mathematical models on which they are most sensitive.
 2. Using historical process data we choose a number of different precedents represented by attribute values, complemented by expert generated precedents in areas where there is not enough information.



APPLICATION OF CBR FOR SUPERVISORY CONTROL OF WWTP


Generation of Case Base with optimal cases

3. Off-line solution of the problem of static optimal control of biological treatment, which is worded as follows:

For known values of attributes of a particular precedent to find optimal values of the control outputs on supervisory level that are set-points of the controllers of first hierarchical level, so as to satisfy the optimality criterion:

minimum energy consumption for aeration E_{aer} / Q_{in}
and / or a minimum consumption of chemicals (z),

wherein subject to the restrictions on the concentrations of the components in the purified water, level of sludge in the secondary clarifier and the concentration of dissolved oxygen.



APPLICATION OF CBR FOR SUPERVISORY CONTROL OF WWTP

1. Definition of the WasteWater Class Attributes

The screenshot displays the Protégé 3.4.4 software interface for defining class attributes. The main window is titled "WasteWater Protégé 3.4.4 (file:G:\testow%20cbr\WasteWater.pprj, Protégé Files (.pont and .pins))". The interface includes a menu bar (File, Edit, Project, Window, Code, MyCBR, Collaboration, Tools, Help) and a toolbar with various icons. Below the toolbar, there are tabs for "Classes", "Slots", "Forms", "Instances", "Queries", "Explanation Editor", "CBR Retrieval", and "Similarity Measure Editor".

The "SLOT BROWSER" panel on the left shows a "Slot Hierarchy" for the "WasteWater" project. The hierarchy includes slots such as BODe, BODin, CaseStr, CODE, Code, CODin, DOSr, FM_cod (highlighted), HRT, MLSS, PO4_Pe, Qa, Qcrab, Qf, Qin, Qr, Qw, Sludg_age, SNHe, SNHin, SNOe, Ssin, TNe, TNin, TPe, TPin, and TSSe.

The "SLOT EDITOR" panel on the right is titled "For Slot: FM_cod (instance of: STANDARD-SLOT)". It contains the following fields and options:

- Name:** FM_cod
- Value Type:** Float
- Documentation:** (Empty text area)
- Template Values:** (Empty text area)
- Default Values:** (Empty text area)
- Cardinality:**
 - required
 - multiple
 - at least: (Empty text box)
 - at most: 1
- Minimum:** 0.0
- Maximum:** 100.0
- Inverse Slot:** (Empty text area)
- Domain:** WasteWater



APPLICATION OF CBR FOR SUPERVISORY CONTROL OF WWTP

2. Creation of a Class and adding Attributes to the Class

WasteWater Protégé 3.4.4 (file:\G:\testow%20cbr\WasteWater.pprj, Protégé Files (.pont and .pins))

File Edit Project Window Code MyCBR Collaboration Tools Help

Classes Slots Forms Instances Queries Explanation Editor CBR Retrieval Similarity Measure Editor

CLASS BROWSER
For Project: WasteWater

Class Hierarchy

- :THING
 - :SYSTEM-CLASS
 - :ANNOTATION
 - :CONSTRAINT
 - :META-CLASS
 - :RELATION
 - :DIRECTED-BINARY-RELATION
 - WasteWater

CLASS EDITOR
For Class: WasteWater (instance of :STANDARD-CLASS)

Name: WasteWater

Documentation:

Constraints:

Role: Concrete

Template Slots

Name	Cardinality	Type	Other Facets
BODe	single	Float	minimum=0.0, maximum=50.0
BODin	single	Integer	minimum=0, maximum=500
CaseStr	single	String	
CODe	single	Float	minimum=0.0, maximum=200.0
Code	single	Integer	minimum=1, maximum=1000
CODin	single	Integer	minimum=1, maximum=800
DOSr	single	Float	minimum=0.0, maximum=100.0
FM_cod	single	Float	minimum=0.0, maximum=100.0
HRT	single	Float	minimum=0.0, maximum=150.0
MLSS	single	Integer	minimum=100, maximum=10000
PO4_Pe	single	Float	minimum=0.0, maximum=100.0
Qa	single	Float	minimum=0.0, maximum=5000.0
Qcrab	single	Float	minimum=0.0, maximum=100.0
Qf	single	Float	minimum=0.0, maximum=100.0
Qin	single	Float	minimum=200.0, maximum=1800.0
Qr	single	Float	minimum=0.0, maximum=5000.0
Qw	single	Float	minimum=0.0, maximum=5000.0
Sludg_age	single	Float	minimum=0.0, maximum=100.0
SNHe	single	Float	minimum=0.0, maximum=10.0
SNHin	single	Float	minimum=0.0, maximum=100.0

Superclasses: :RELATION

APPLICATION OF CBR FOR SUPERVISORY CONTROL OF WWTP

3. Definition of Local Similarity Function of DOsr Attribute

The screenshot displays the 'SIMILARITY MEASURE EDITOR' window. On the left, the 'CLASS BROWSER' shows a hierarchy for 'WasteWater' under ':RELATION'. Below it, the 'SLOT BROWSER' lists attributes for 'WasteWater', with 'DOsr' selected. The main area is titled 'SIMILARITY MEASURE EDITOR' and contains the following controls:

- Available Functions:** A list with 'default' selected. Buttons for 'New', 'Duplicate', 'Delete', and 'Active' are present.
- Similarity mode:** Set to 'Standard'.
- Symmetry:** Radio buttons for 'symmetric' and 'asymmetric' (selected).
- Distance Function:** Radio buttons for 'difference' (selected) and 'quotient'.
- Step at:** Two input fields, both set to '0.0'.
- Polynomial with:** Two input fields, both set to '1.0'.
- Smooth-Step at:** Two input fields, both set to '50.0'.
- Constant:** Two input fields, both set to '1.0'.

Below these controls is a graph showing a triangular similarity function. The x-axis ranges from -100 to 100, and the y-axis ranges from 0 to 1.0. The function is defined as:

$$f(x) = \begin{cases} 0 & \text{if } x < -100 \\ \frac{x + 100}{100} & \text{if } -100 \leq x < 0 \\ 1.0 & \text{if } x = 0 \\ \frac{100 - x}{100} & \text{if } 0 < x \leq 100 \\ 0 & \text{if } x > 100 \end{cases}$$

The graph is labeled 'case < query' on the left and 'case > query' on the right. To the right of the graph is a vertical axis labeled 'Explanations' with a scale from 0 to 20. A small bar chart shows a peak at 0 with a value of approximately 5. A 'Refresh Explanation Manager' button is located above the graph.

APPLICATION OF CBR FOR SUPERVISORY CONTROL OF WWTP

4. Definition of Local Similarity Function of CODE Attribute

The screenshot displays the 'SIMILARITY MEASURE EDITOR' window. On the left, the 'CLASS BROWSER' shows a project named 'WasteWater' with a class hierarchy including :SYSTEM-CLASS, :ANNOTATION, :CONSTRAINT, :META-CLASS, :RELATION, and :DIRECTED-BINARY-RELAT. Below it, the 'SLOT BROWSER' lists various slots for the 'WasteWater' class, such as BODe, Case_Id, CODE, DOsr, Eaeer_Qln, expert_w, HRT, MLSS, Qa, Qaer, Qcarb, Qln, Qr, Qw, SNHdn, and SNHe.

The main area of the editor is titled 'SIMILARITY MEASURE EDITOR' and contains the following elements:

- Available Functions:** A list with 'default' selected. Buttons for 'New', 'Duplicate', 'Delete', and 'Active' are present.
- Similarity mode:** Set to 'Advanced'.
- Symmetry:** Radio buttons for 'symmetric' and 'asymmetric', with 'asymmetric' selected.
- Distance Function:** Radio buttons for 'difference' and 'quotient', with 'difference' selected.
- Basic Similarity Points:** A table with columns 'Distance' and 'Similarity':

Distance	Similarity
Min	0.0
0	1.0
Max	0.0
- Additional Similarity Points:** A table with columns 'Distance' and 'Similarity':

Distance	Similarity
-120.0	0.08
-80.0	0.24
-40.0	0.53
120.0	0.86
180.0	0.68
- Graphs:** A line graph shows the similarity function for 'case < query' (left side) and 'case > query' (right side). The x-axis ranges from -200 to 200, and the y-axis ranges from 0 to 1.0. A red histogram shows the distribution of values for the 'CODE' attribute, with a peak around 50.

APPLICATION OF CBR FOR SUPERVISORY CONTROL OF WWTP

5. Definition of Global Similarity Function for WasteWater

Classes Slots Forms Instances Queries Explanation Editor CBR Retrieval Similarity Measure Editor

CLASS BROWSER
For Project: WasteWater

Class Hierarchy

- :THING
 - :SYSTEM-CLASS
 - :ANNOTATION
 - :CONSTRAINT
 - :META-CLASS
 - :RELATION
 - :DIRECTED-BINARY-RELAT
 - WasteWater

SLOT BROWSER
For class WasteWater

Slot Hierarchy

- BODe
- Case_Id
- CODe
- DOsr
- Eaer_Qin
- expert_w
- HRT
- MLSS
- Qa
- Qaer

SIMILARITY MEASURE EDITOR

Available Functions:
default [New] [Duplicate] [Delete] [Active] "default" is the active similarity measure

Similarity mode: Standard [i]

Attributes (Slots):

attribute	discriminant	weight	Local SMF	comment
BODe	100% <input type="checkbox"/>		1 Active SMF	no local similarity measure :
CODe	100% <input checked="" type="checkbox"/>		1 Active SMF	
Case_Id	100% <input checked="" type="checkbox"/>		1 Active SMF	
DOsr	100% <input checked="" type="checkbox"/>		1 Active SMF	
Eaer_Qin	100% <input checked="" type="checkbox"/>		1 Active SMF	
HRT	100% <input checked="" type="checkbox"/>		1 Active SMF	
MLSS	100% <input checked="" type="checkbox"/>		1 Active SMF	
Qa	100% <input checked="" type="checkbox"/>		1 Active SMF	
Qaer	100% <input checked="" type="checkbox"/>		1 Active SMF	
Qcarb	100% <input checked="" type="checkbox"/>		1 Active SMF	
Qin	100% <input checked="" type="checkbox"/>		1 Active SMF	
Qr	100% <input checked="" type="checkbox"/>		1 Active SMF	
Qw	100% <input type="checkbox"/>		1 Active SMF	no local similarity measure :
SNHdn	100% <input checked="" type="checkbox"/>		1 default	
SNHe	100% <input checked="" type="checkbox"/>		1 Active SMF	
SNHin	100% <input checked="" type="checkbox"/>		1 default	
SNOdn	100% <input checked="" type="checkbox"/>		1 default	
SNOe	100% <input type="checkbox"/>		1 Active SMF	no local similarity measure :
SRT	100% <input type="checkbox"/>		1 Active SMF	no local similarity measure :
SolutionStr	30% <input type="checkbox"/>		1 Active SMF	no local similarity measure :
TNe	100% <input type="checkbox"/>		1 Active SMF	no local similarity measure :
expert_w	100% <input type="checkbox"/>		1 Active SMF	

Weighted Sum Minimum
 Euclidean Maximum

APPLICATION OF CBR FOR SUPERVISORY CONTROL OF WWTP

6. Creating Cases (instances of a Class) via Instance Editor

The screenshot displays the Protégé 3.4.4 Instance Editor window. The title bar indicates the file path: (file:\G:\testow%20cbr\WasteWater.pprj, Protégé Files (.pont and .pins)). The menu bar includes File, Edit, Project, Window, Code, MyCBR, Collaboration, Tools, and Help. The toolbar contains various icons for file operations and editing. The main interface is divided into several panes:

- Classes:** Shows a tree view of classes, with 'WasteWater' selected.
- Instances:** Shows a list of instances, with 'WasteWater_Class10003' selected.
- Instance Editor:** Displays the configuration for the selected instance, 'WasteWater_Class10003 (instance of WasteWater)'. The editor is organized into a grid of input fields for various parameters:

Parameter	Value
Qin	496.1
CODin	223
FM Cod	0.106
DOsr	2.93
Qa	2305.8
SNHe	0.97
SHOe	10.0
BODin	113
Ssin	40.0
MLSS	4710
Qr	768.6
Qw	16.0
TSSe	10.7
TNe	12.7
TNin	32.0
SNHin	20.0
Sludg Age	6.0
Qcrab	15.0
Qf	0.0
TPe	0.0
BODe	2.33
TSSin	114
HRT	14.78
CODE	45.1
TPin	1.0
P04 Pe	1.0
Code	5
CaseStr	TEXT FOR CASE specific data or links



APPLICATION OF CBR FOR SUPERVISORY CONTROL OF WWTP

7. Case Retrieval (Query to Case Base database)

WasteWater Protégé 3.4.4 (file:\G:\testow%20cbr\WasteWater.pprj, Protégé Files (.pont and .pins))

File Edit Project Window Code MyCBR Collaboration Tools Help

Classes Slots Forms Instances Queries Explanation Editor CBR Retrieval Similarity Measure Editor

DETAILS AND QUERY

WasteWater Retrieve Load Save Clear Reset < Previous > Next

Query	WasteWater_Class40001 1 0.94	WasteWater_Class20003 2 0.93	WasteWater_Class20001 3 0.93
BODe	2.54	3.09	3.08
BODin	300	206	206
CODe	47.2	50.0	49.9
CODin	400	408	408
CaseStr			
Code	17	13	11
DOsr	1.45	1.89	1.91
FM_cod	0.5	1.0	1.0
HRT	10.68	8.19	8.63
MLSS	3500	4900	4870
PO4_Pe	1.0	1.0	1.0
Qa	2305.8	2305.8	
Qcrab	10.0	10.0	
Qf	0.0	0.0	
Qin	1000.0	894.9	849.9
Qr	768.6	638.6	558.6
Qw	16.0	16.0	15.0
SNHe	1.54	1.92	2.0
SNHin	35.0	30.2	30.2
SNOe	9.55	9.57	9.53
Sludg_age	5.21	4.08	4.02
Ssin	84.2	63.6	63.6
TNe	12.9	13.6	13.6
TNin	61.8	54.4	54.4
TPe	0.0	0.0	0.0
TPin	1.0	1.0	1.0
TSSe	12.2	14.3	14.3
TSSin	233	236	236

WasteWater_Class20003
MLSS = 4900 => similarity = 0.86

QUERY RESULTS

- WasteWater... 0.94
- WasteWater... 0.93
- WasteWater... 0.93
- WasteWater... 0.92
- WasteWater... 0.92
- WasteWater... 0.92
- WasteWater... 0.92
- WasteWater... 0.92
- WasteWater... 0.92
- WasteWater... 0.92
- WasteWater... 0.91
- WasteWater... 0.91
- WasteWater... 0.91
- WasteWater... 0.91
- WasteWater... 0.86
- WasteWater... 0.85
- WasteWater... 0.85
- WasteWater... 0.83
- WasteWater... 0.83
- WasteWater... 0.82

Start: 3:40:17
Finish: 3:40:17
Duration: 0.010 sec

CONCLUSIONS

- An approach for supervisory control of biological purification of waste water is developed.
- The approach is based on a combination of off-line solving the optimization problem in order to form the initial Case Base and optimal real-time control using (Case Based Reasoning).
- For software implementation is used myCBR – a plug-in of ontology editor Protégé.
- If for new specific case the realized control output is optimal, this precedent (case) is added to the Case Base database with which it is updated continuously.



CONCLUSIONS

- Proposed CBR solution for optimal WWTP control guarantee the quality of purified water and biogas parameters (65% methane).
- It is applied in Co-generation units with max electricity/thermal power of 160/177 kW in town of Sliven, Varna, etc.
- Similar CBR control can be applied to Co-generation power stations, as well in other installations related to specific RES.
- For example CBR recommender systems for selecting optimal places or prices for building PV plants.



The left side of the slide features a decorative vertical stripe composed of several parallel lines in varying shades of light blue. To the right of this stripe, there is a vertical arrangement of five teal-colored circles of different sizes, with the largest circle at the top and the smallest at the bottom. The text is positioned to the right of these circles.

**THANK YOU FOR
YOUR ATTENTION!**