

# Ecological Interface Design

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## Conventional display design

- ◆ Display design based on Single Sensor - Single Indicator (SSSI) concept or Piping and Instrumentation Diagram (P&ID)
- ◆ Problems
  - Task relevant information of the system is not presented explicitly.
  - Operators need to integrate pieces of data to identify the system state.
  - Display style does not necessarily match operator's cognitive characteristics.



## Ecological view of cognition

- ◆ A cognitive system is constructed so that an organism can extract information relevant for survival from the environment and select appropriate actions at once.
- ◆ A human information processor is an illusory substance. An organism can perceive relevant information directly without analyzing or decomposing the elementary features of input data.



## Affordance (J.J.Gibson)

- ◆ The features of an object to be sensed directly by organisms that are relevant for their survival and behavior.
  - The shape of a chair affords to sit on.
  - The shape of a picket affords to stick.
  - A circle affords to round.
  - An inverted triangle affords instability.

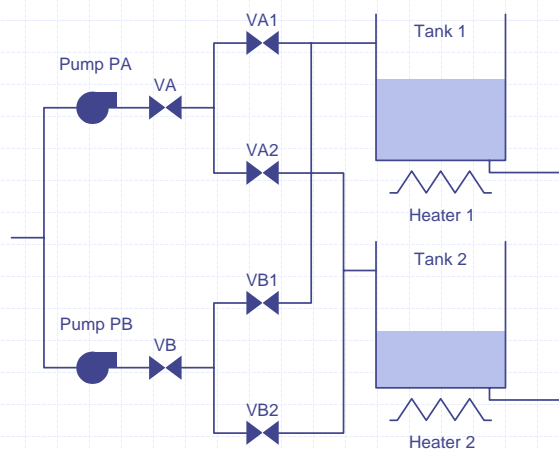


## Ecological Interface Design

- ◆ Visualize the usage of displays and controls for the purpose of task goal (Abstraction Hierarchy).
- ◆ Visualize the constraints embedded in the target system or the task environment.
- ◆ Adopt direct manipulation as much as possible to utilize the sensory-motor skill of a human.

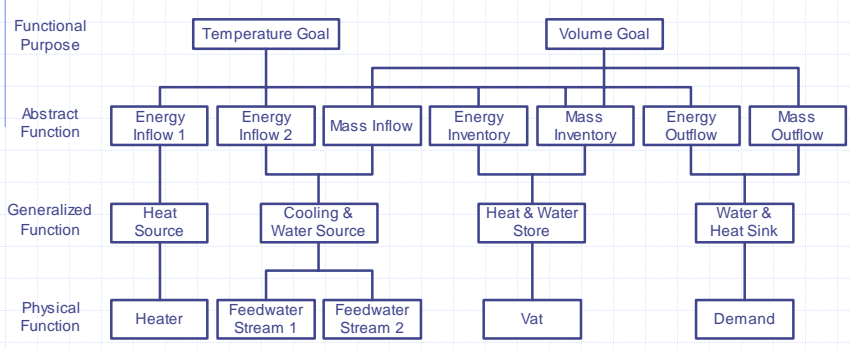


## DUAL Reservoir Supply System





## Means-ends hierarchy of DURESS



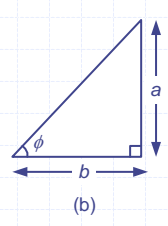
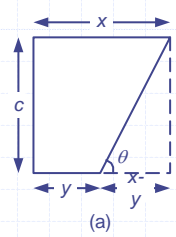
## Mapping constraint on geometry

$$\frac{dV}{dt} = \frac{W_{in} - W_{out}}{\rho}$$

$$\cot \theta = \frac{x - y}{c}$$

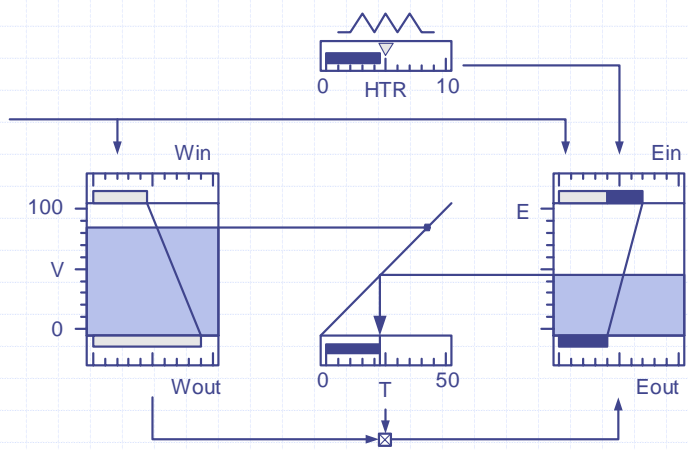
$$T = \frac{E}{V\rho C_p}$$

$$T = \frac{a}{\tan \phi}$$

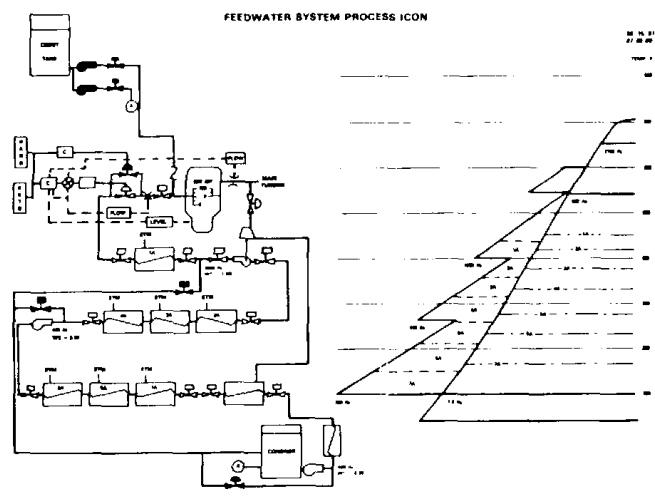




## Example of DURESS EID



## Rankin-cycle display



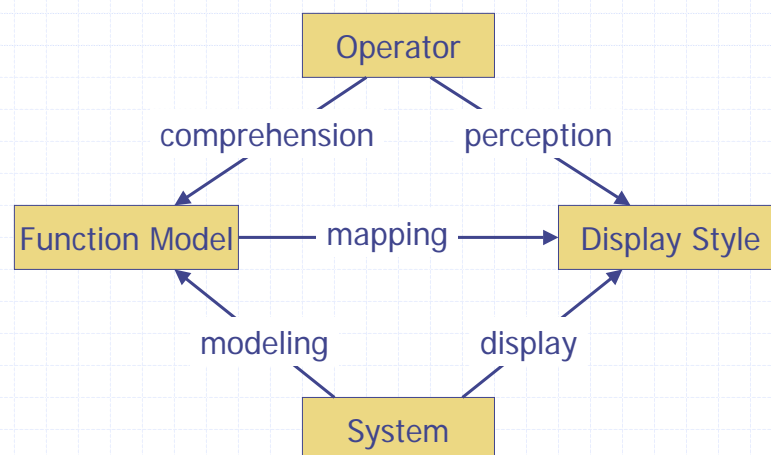


## Advanced display design

- ◆ Explicit presentation of goal-mean relations, functions, or meaning of information.
- ◆ Problems
  - Design methodology is too conceptual and heavily relies on designer's craftsmanship.
  - Most works show just a few application examples, but generality of method is questionable.
  - Integrated display within a single screen is preferred without considering application to large-scale systems.
  - Application to control systems is not considered.



## Concept of EID method





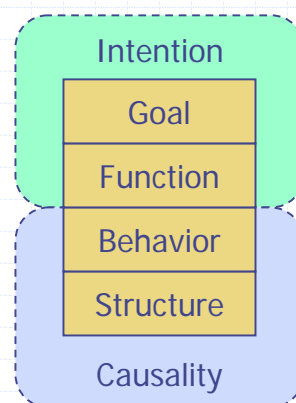
## Basic concepts

- Goal: Objective of the system assigned by designer
- Function: The role of subsystem or device expected for achieving the goal
- Behavior: Physical behavior that subsystem or device shows under a certain condition
- Structure: Physical configuration of system components

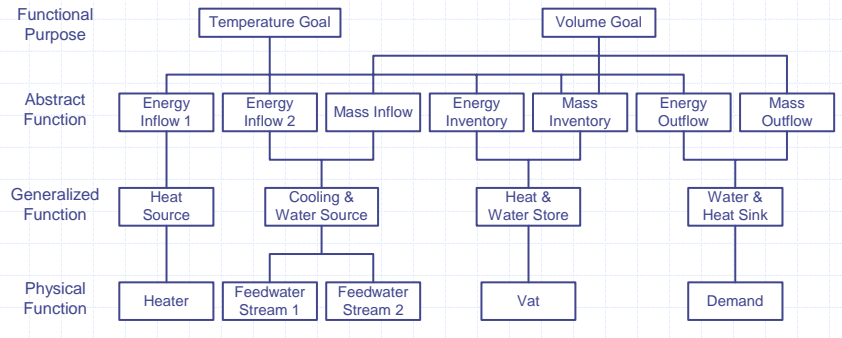
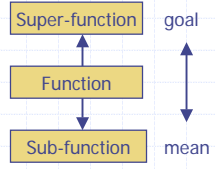


## Relation between basic concepts

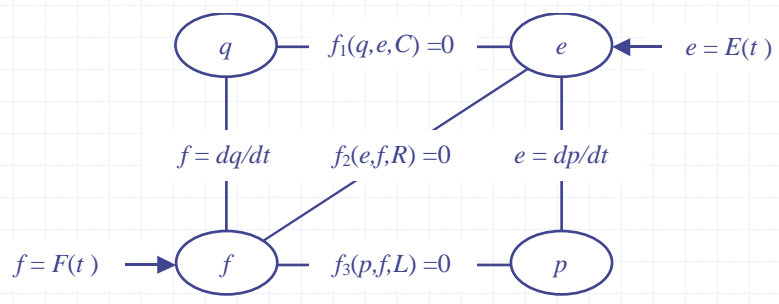
- ◆ Function provides interpretation on behavior and mediates between aspects on physical causality and those on human intention.



# Function hierarchy of DURESS



# Tetrahedron of states



## Function primitives for physical processes (1)



Math formulation	Bond graph	MFM	Functional role model	Proposal
$e = E(t)$	effort source		e-generator	generate
$f = F(t)$	flow source	source	f-generator	
$C \cdot df/dt = e$	capacity	store	q-reservoir	store
$L \cdot de/dt = f$	inertia		p-reservoir	
$f_{out} = f_{in}, \Delta e = R \cdot f$	resistance	transport	f-conduit	transport
$e_{out} = e_{in}, \Delta f = R \cdot e$			e-conduit	
$e_{out} = k \cdot e_{in}, f_{out} = f_{in}/k$	transformer			transform
$e_{out} = k \cdot f_{in}, f_{out} = e_{in}/k$	gyrator			
$y = f(x)$				

## Function primitives for physical processes (2)



Math formulation	Bond graph	MFM	Functional role model	Proposal
$\sum f = 0$	flow distributor	balance		balance
$\sum e = 0$	effort distributor			
$f = 0$		barrier	f-barrier	barrier
$e = 0$			e-barrier	
$f = F(t)$		sink	f-conduit	sink
$e = E(t)$			e-conduit	

## Function primitives for control systems (1)



Function Label	Math Formulation	Category
control	$y = y_{set}$	control
rate control	$dy / dt = v_{set}$	
closed loop dynamics	$y \Rightarrow y_{set}$	
measure	$y = f(t)$	generate
generate	$y = f(t)$	
set manually	$y \leftarrow$	set
set automatically	$y \leftarrow$	

## Function primitives for control systems (2)



Function Label	Math Formulation	Category
select manually	$y = mselect(x_1, \dots, x_n)$	select
select automatically	$y = select(x_1, \dots, x_n)$	
select low value	$y = \min(x_1, \dots, x_n)$	
select high value	$y = \max(x_1, \dots, x_n)$	
subtract	$y = x_0 - x_1 - \dots - x_n$	calculate
sum	$y = x_1 + x_2 + \dots + x_n$	
transform	$y = f(x)$	transform
dynamic transform	$y \Rightarrow f(x)$	

## Function primitives for control systems (3)



Function Label	Math Formulation	Category
limit	$y = \lim(x; x_{\min} \leq x)$ $y = \lim(x; x \leq x_{\max})$ $y = \lim(x; x_{\min} \leq x \leq x_{\max})$	limit
derivate	$y = dx/dt$	derivate / integrate
integrate	$y = \int xdt + y_0$	
PID transform	$y = g_1x + g_2dx/dt + g_3(\int xdt + y_0)$	
delay	$y = x(t - \tau)$	delay
1st order lag	$\tau \cdot dy/dt + y = Kx$	

## References to function primitives



Function Label	Vocabulary
generate	produce, form, supply, make, ...
store	accumulate, reserve, keep, ...
transport	carry, transfer, move, circulate, ...
transform	convert, derive, reform, ...
balance	keep, hold, maintain, retain, ...
barrier	prohibit, suppress, limit, ...
sink	exit, exhaust, output, ...



## Function Modeling (FM)

### ◆ Semantics

<function, parameter, subsystem/component,  
constraint, context>

<maintain, level ( $L$ ), expansion tank,  
 $1.1\text{m} < L < 1.2\text{m}$ , in operation>

### ◆ Expansion of function hierarchy starting from the system's top goal down to some level of enough detail



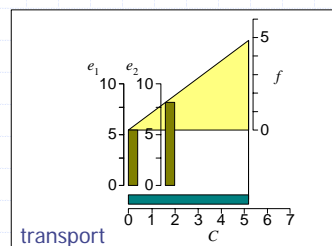
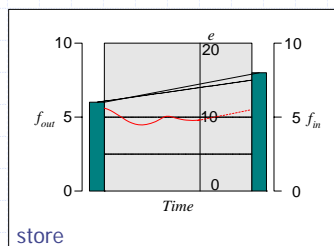
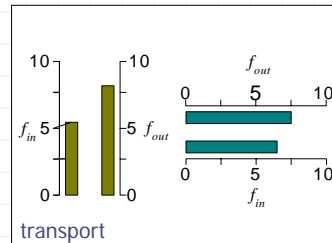
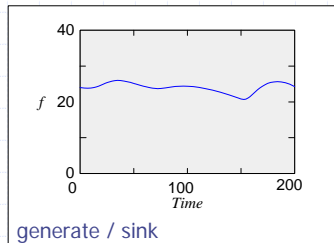
## Display style library

### ◆ Visualize mathematical constraint as geometrical constraint

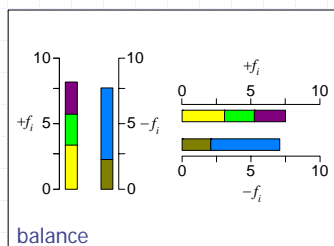
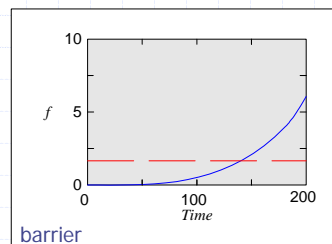
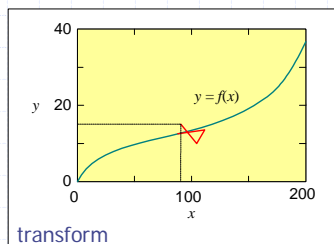
### ◆ Intuitively perceptible expression

- length of line
- gradient of line
- parallelism of lines
- distance between points
- distance between point and line

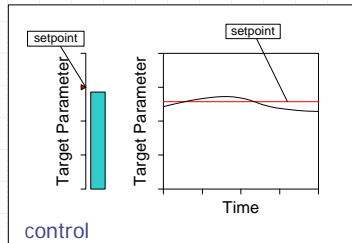
# Display style library for Physical Processes (1)



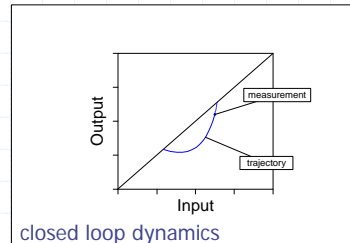
# Display style library for physical processes (2)



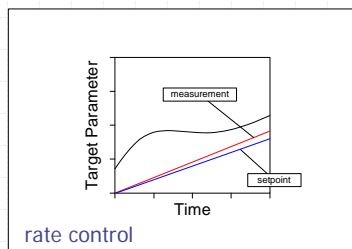
# Display style library for control systems (1)



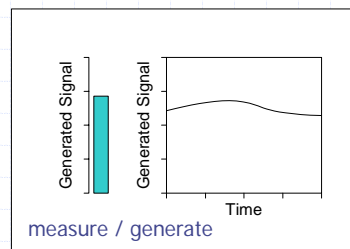
control



closed loop dynamics

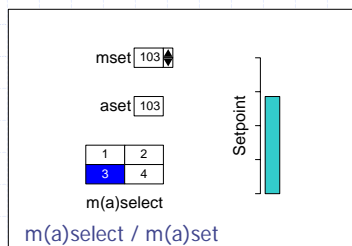


rate control

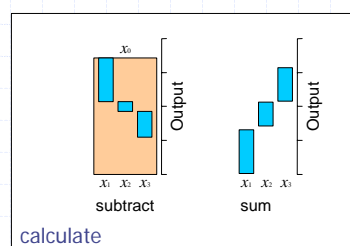


measure / generate

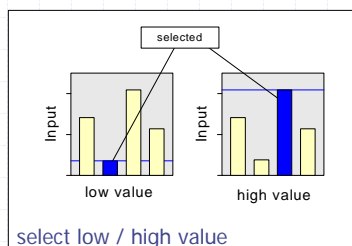
# Display style library for control systems (2)



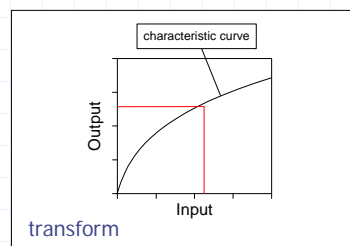
m(a)select / m(a)set



calculate

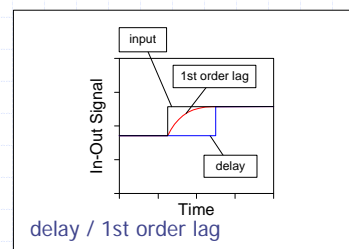
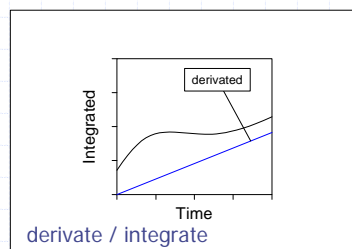
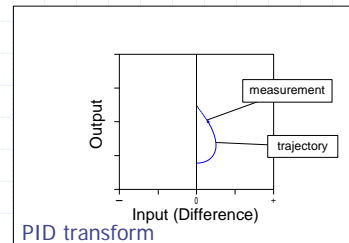
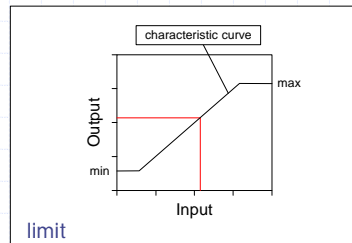


select low / high value



transform

## Display style library for control systems (3)

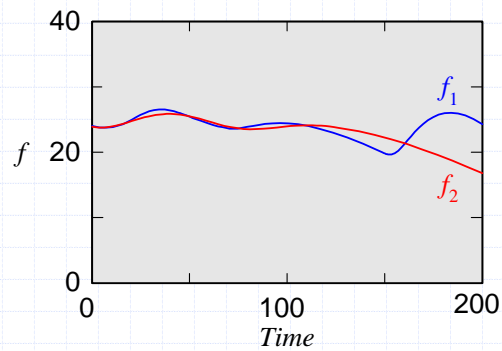
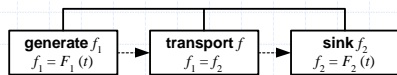


## Function macro

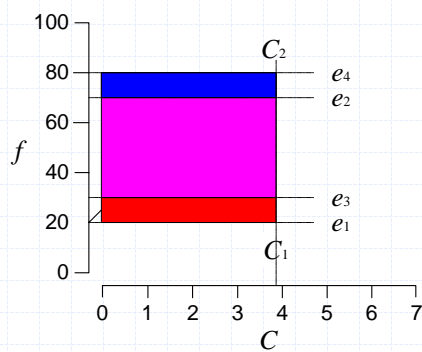
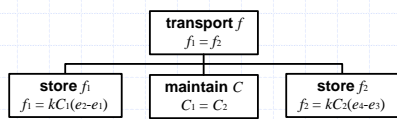


- ◆ Pattern of function primitives that appear frequently in FMs and recognizable as a chunk
- ◆ Display style library for function macros
  - Saving of display area
  - Better comprehension of system function as a chunk

## Display style of function macro (1)



## Display style of function macro (2)



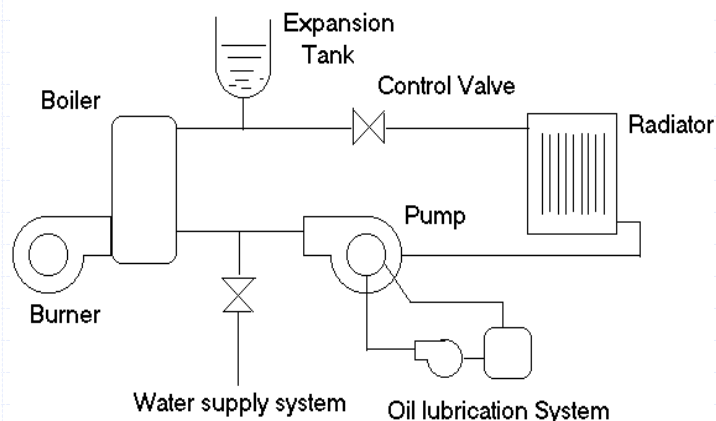


## Design of display hierarchy

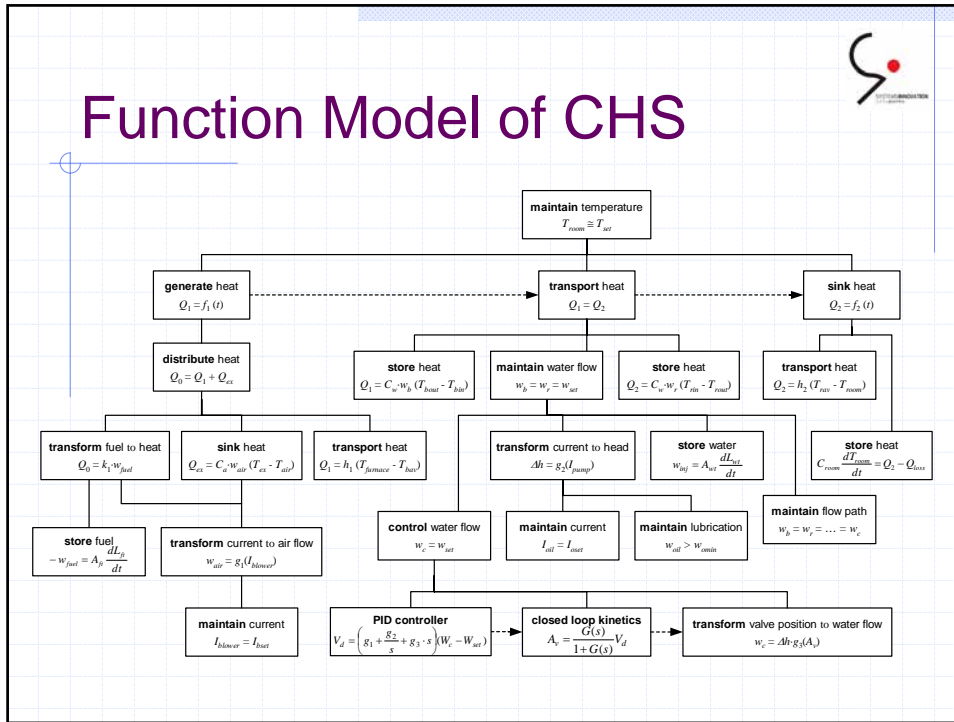
- ◆ Determine parts of FM to be displayed
  - Based on tasks expected for operators
- ◆ Search for function macro from the top
  - If no macros, pick up function primitive
- ◆ Add corresponding display style to display
  - Mark functions already mapped on display
- ◆ Repeat width-first search descending function hierarchy
  - Generate structure isomorphic to function hierarchy



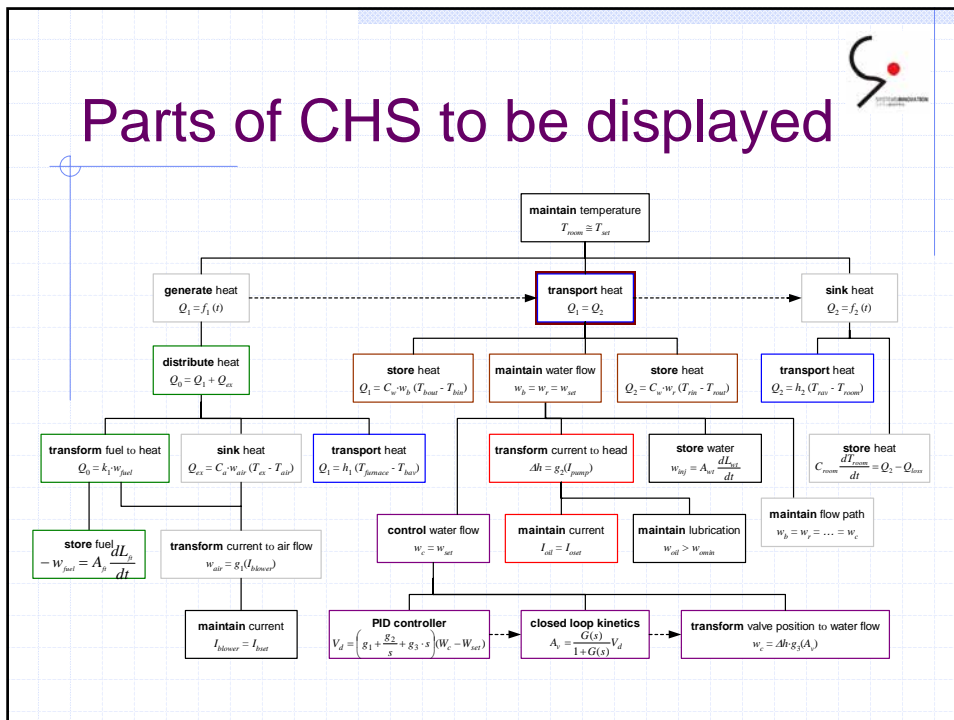
## Central Heating System (CHS)



# Function Model of CHS



# Parts of CHS to be displayed



# Display hierarchy for CHS

