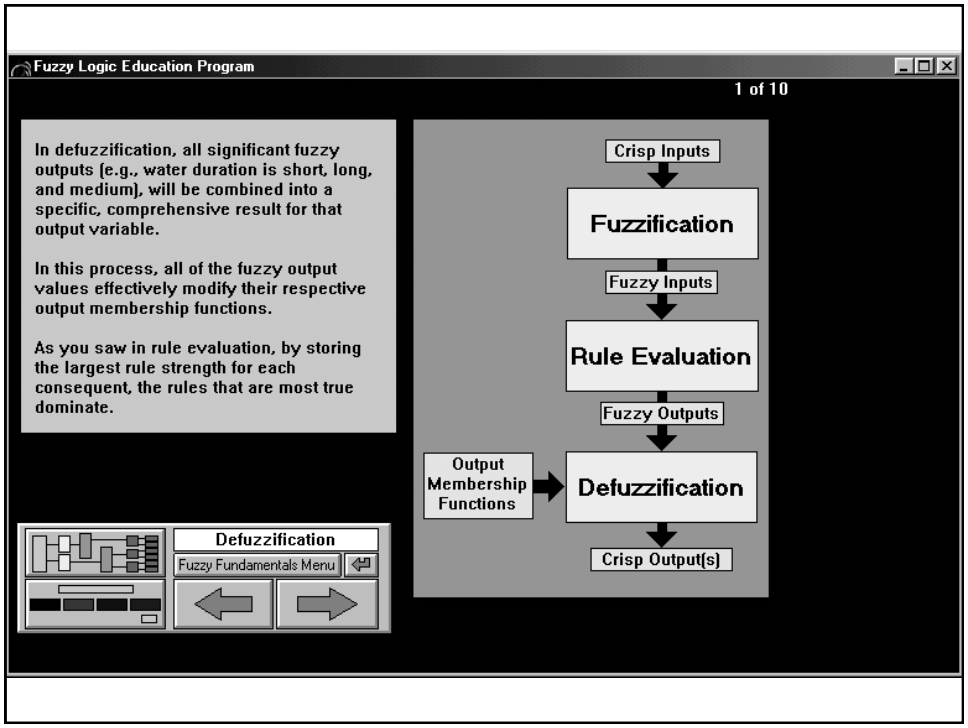
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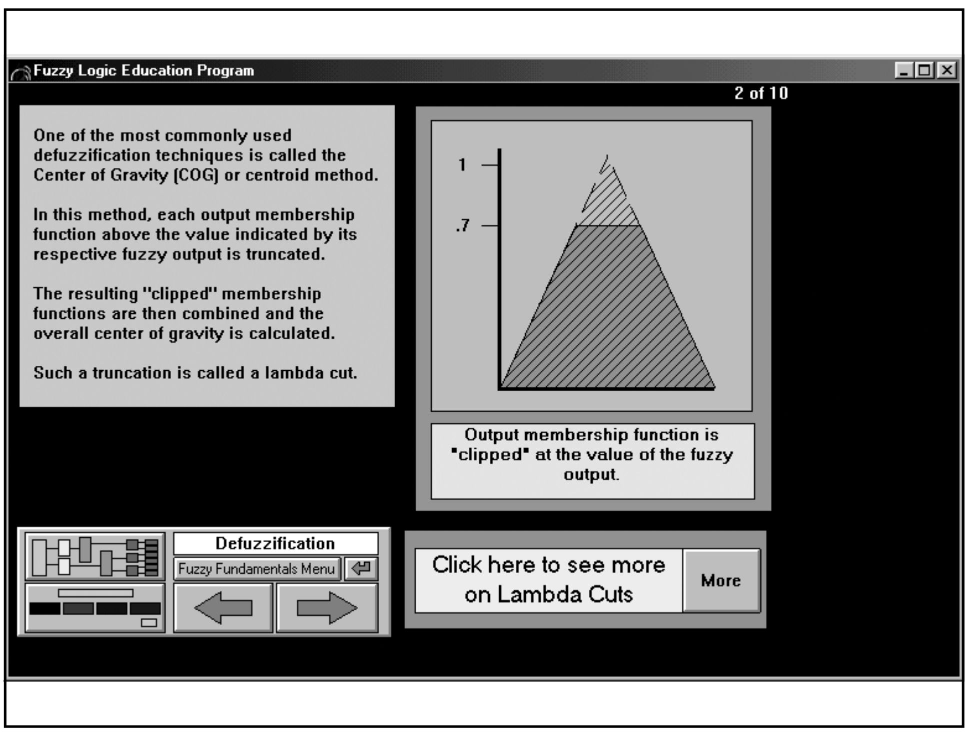
In defuzzification, all significant fuzzy outputs (e.g., water duration is short, long, and medium), will be combined into a specific, comprehensive result for that output variable.
In this process, all of the fuzzy output values effectively modify their respective output membership functions.
As you saw in rule evaluation, by storing the largest rule strength for each consequent, the rules that are most true dominate.
Crisp Inputs
Fuzzification
Fuzzy Inputs
Rule Evaluation
Fuzzy Outputs
Output Membership Functions
Defuzzification
Crisp Output(s)
Defuzzification
Fuzzy Fundamentals Menu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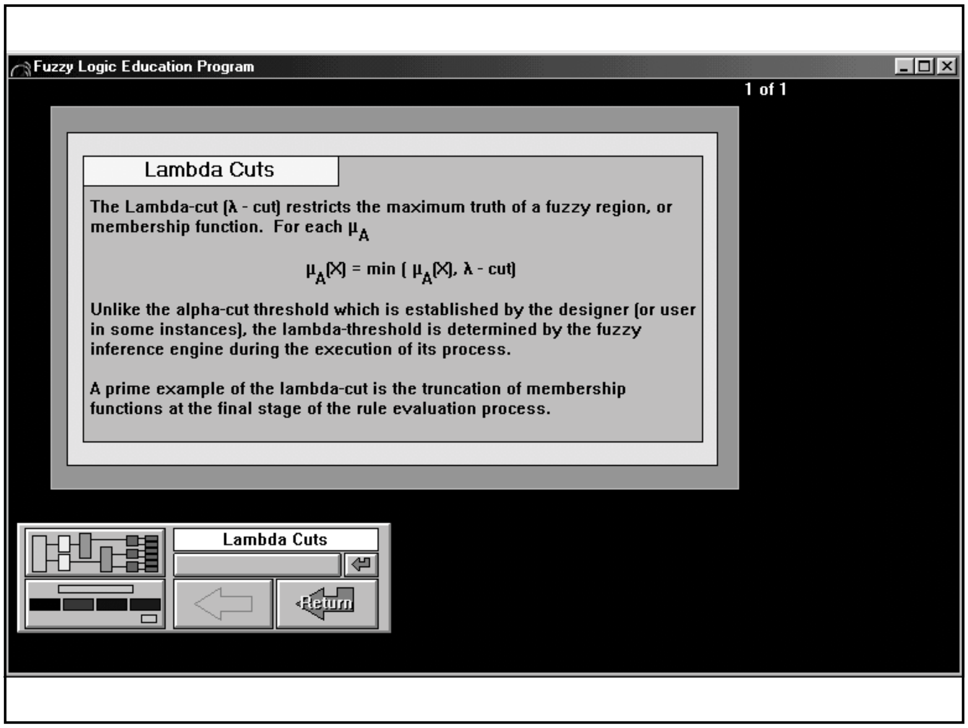
One of the most commonly used defuzzification techniques is called the Center of Gravity (COG) or centroid method.
In this method, each output membership function above the value indicated by its respective fuzzy output is truncated.
The resulting "clipped" membership functions are then combined and the overall center of gravity is calculated.
Such a truncation is called a lambda cut.
1
.7
Output membership function is "clipped" at the value of the fuzzy output.
Defuzzification
Fuzzy Fundamentals Menu
Click here to see more on Lambda Cuts
More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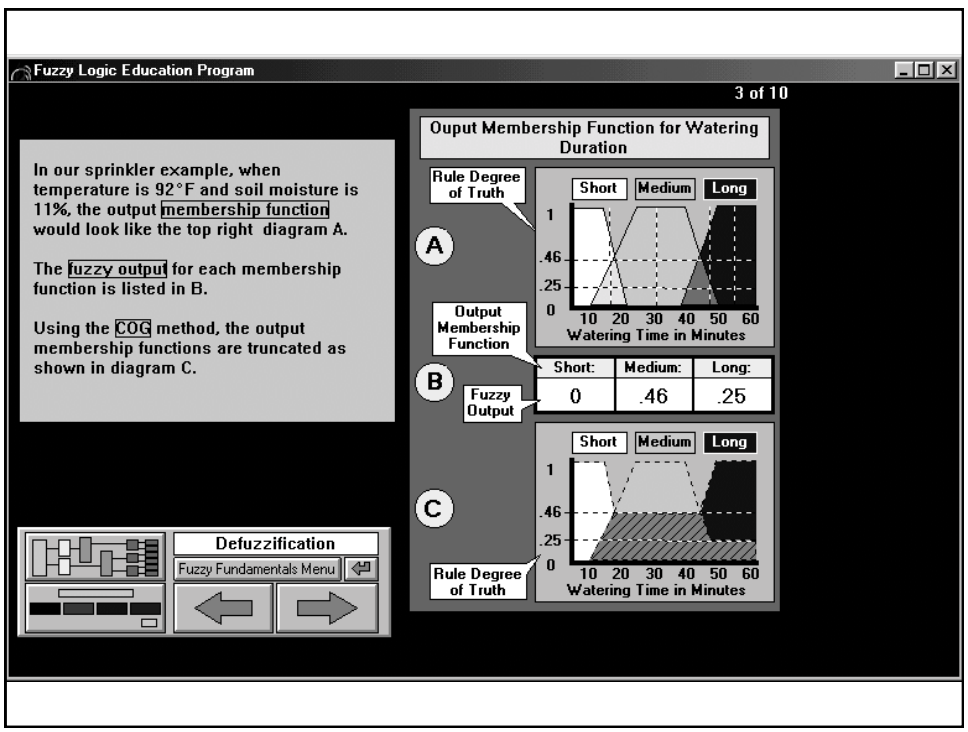
Lambda Cuts
The Lambda-cut (λ - cut) restricts the maximum truth of a fuzzy region, or membership function. For each μA
μA(X) = min (μA(X), λ - cut)
Unlike the alpha-cut threshold which is established by the designer (or user in some instances), the lambda-threshold is determined by the fuzzy inference engine during the execution of its process.
A prime example of the lambda-cut is the truncation of membership functions at the final stage of the rule evaluation process.
Lambda Cuts
Return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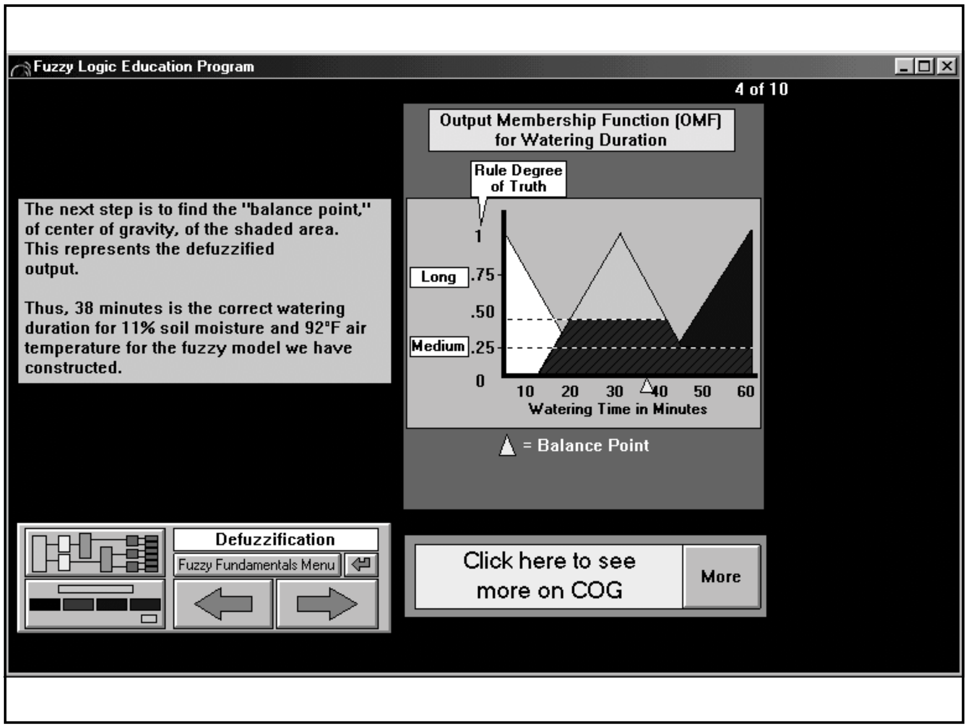
In our sprinkler example, when temperature is 92°F and soil moisture is 11%, the output membership function would look like the top right diagram A.
The fuzzy output for each membership function is listed in B.
Using the COG method, the output membership functions are truncated as shown in diagram C.
Ouput Membership Function for Watering Duration
Rule Degree of Truth
A
Short
Medium
Long
1
.46
.25
0
10 20 30 40 50 60
Watering Time in Minutes
Output Membership Function
B
Short:
Medium:
Long:
0
.46
.25
Fuzzy Output
C
Rule Degree of Truth
Defuzzification
Fuzzy Fundamentals Menu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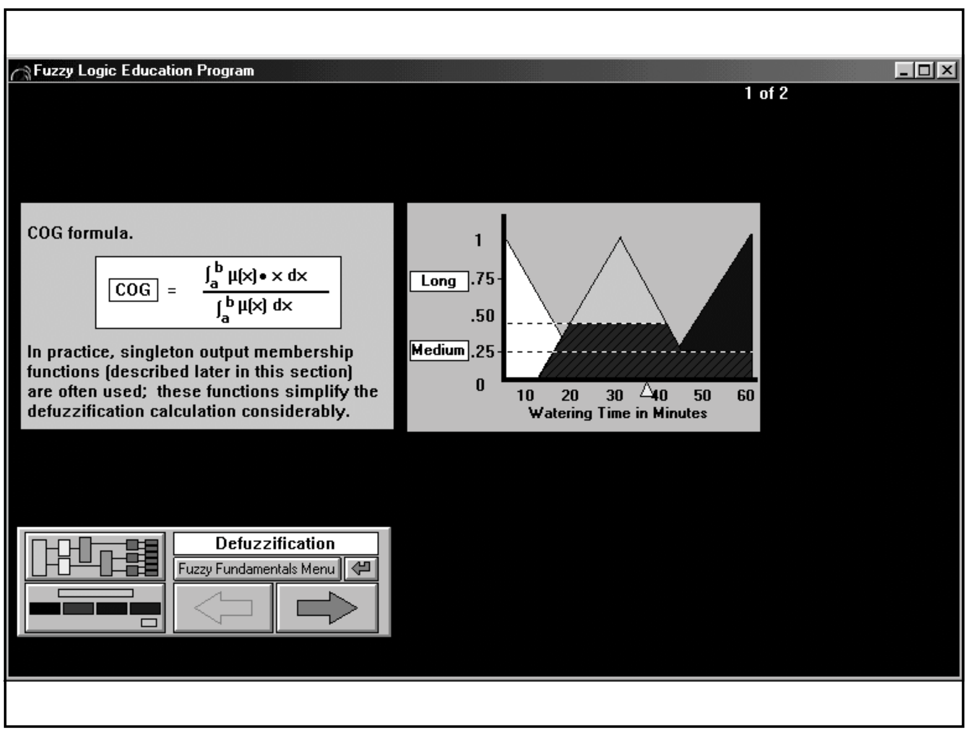
The next step is to find the "balance point," of center of gravity, of the shaded area. This represents the defuzzified output.
Thus, 38 minutes is the correct watering duration for 11% soil moisture and 92°F air temperature for the fuzzy model we have constructed.
Output Membership Function (OMF) for Watering Duration
Rule Degree of Truth
Long
Medium
1
.75
.50
.25
0
10 20 30 40 50 60
Watering Time in Minutes
= Balance Point
Defuzzification
Fuzzy Fundamentals Menu
Click here to see more on COG
More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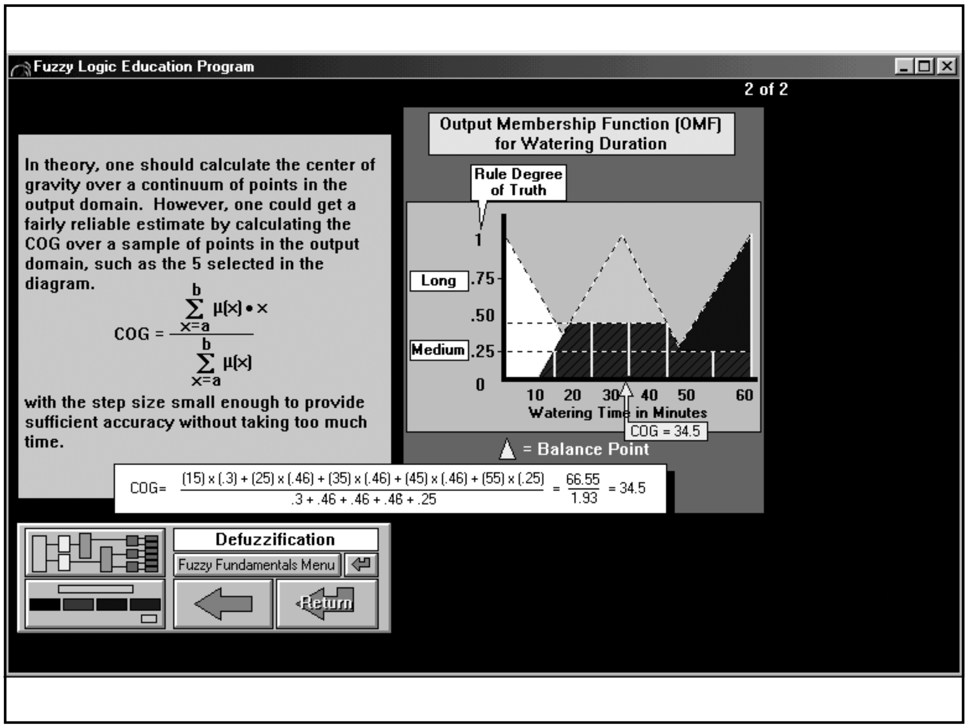
COG formula.
COG = ∫a b μ(x)• x dx / ∫a b μ(x) dx
In practice, singleton output membership functions (described later in this section) are often used; these functions simplify the defuzzification calculation considerably.
Long
Medium
1
.75
.50
.25
0
10 20 30 40 50 60
Watering Time in Minutes
Defuzzification
Fuzzy Fundamentals Menu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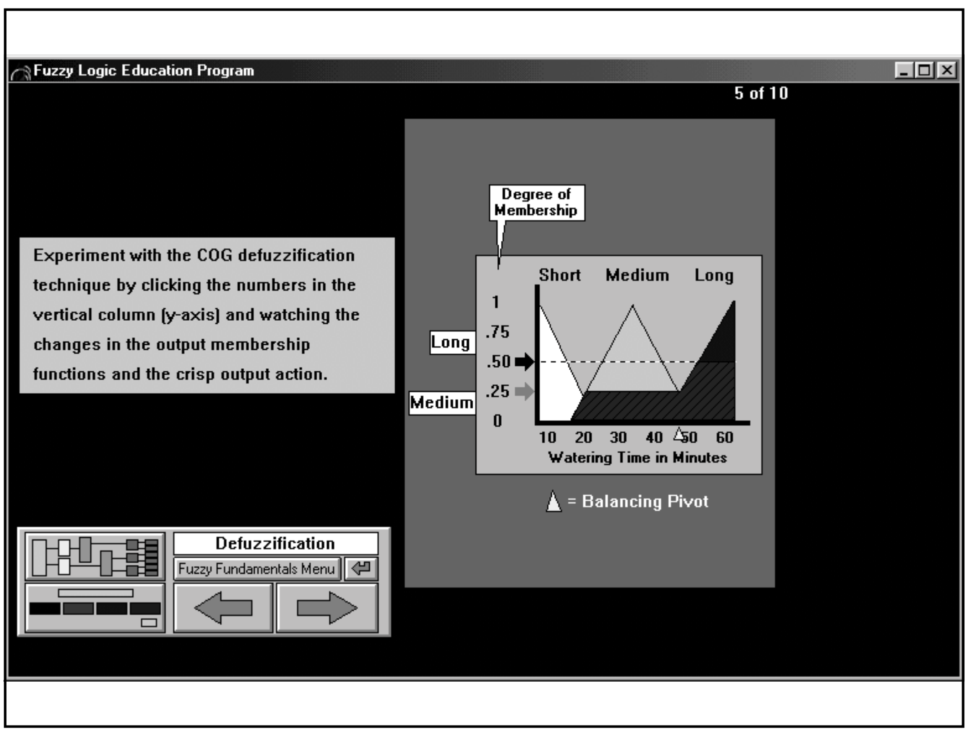
In theory, one should calculate the center of gravity over a continuum of points in the output domain. However, one could get a fairly reliable estimate by calculating the COG over a sample of points in the output domain, such as the 5 selected in the diagram.
$COG = \frac{\sum_{x=a}^{b} \mu(x) \bullet x}{\sum_{x=a}^{b} \mu(x)}$
with the step size small enough to provide sufficient accuracy without taking too much time.
Output Membership Function (OMF) for Watering Duration
Rule Degree of Truth
Long
Medium
1
.75
.50
.25
0
10 20 30 40 50 60
Watering Time in Minutes
COG = 34.5
= Balance Point
$COG = \frac{(15) \times (.3) + (25) \times (.46) + (35) \times (.46) + (45) \times (.46) + (55) \times (.25)}{.3 + .46 + .46 + .46 + .25} = \frac{66.55}{1.93} = 34.5$
Defuzzification
Fuzzy Fundamentals Menu
Return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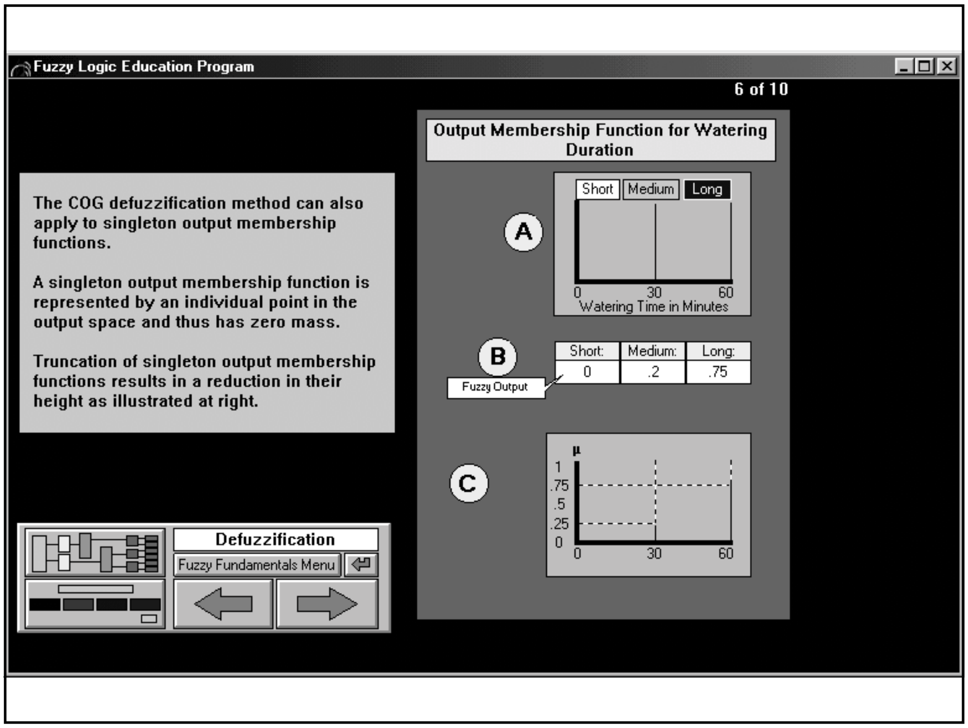
Experiment with the COG defuzzification technique by clicking the numbers in the vertical column (y-axis) and watching the changes in the output membership functions and the crisp output action.
Degree of Membership
Short
Medium
Long
Long
Medium
1
.75
.50
.25
0
10 20 30 40 50 60
Watering Time in Minutes
= Balancing Pivot
Defuzzification
Fuzzy Fundamentals Menu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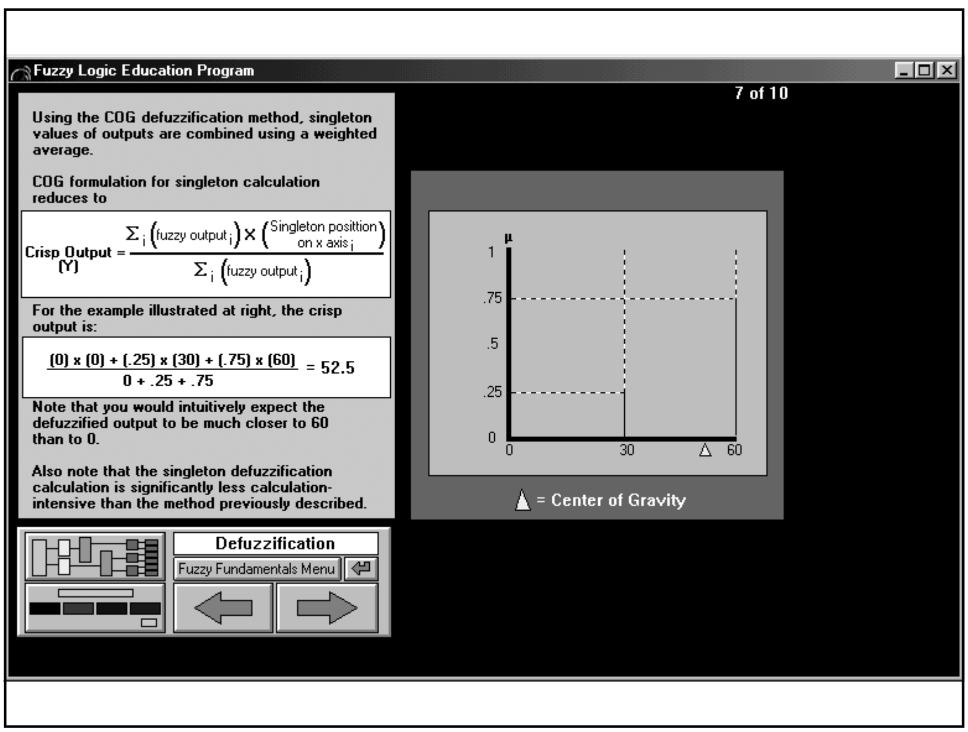
The COG defuzzification method can also apply to singleton output membership functions.
A singleton output membership function is represented by an individual point in the output space and thus has zero mass.
Truncation of singleton output membership functions results in a reduction in their height as illustrated at right.
Output Membership Function for Watering Duration
A
Short Medium Long
0 30 60
Watering Time in Minutes
B
Short: Medium: Long:
0 .2 .75
Fuzzy Output
C
μ
1 .75 .5 .25 0
0 30 60
Defuzzification
Fuzzy Fundamentals Menu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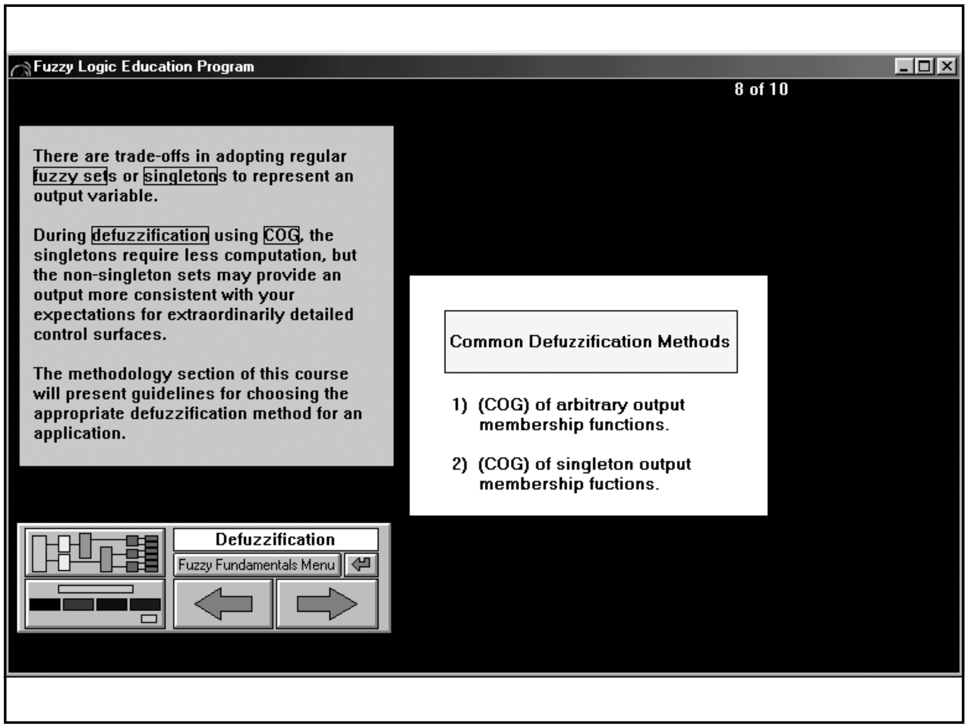
Using the COG defuzzification method, singleton values of outputs are combined using a weighted average.
COG formulation for singleton calculation reduces to
Crisp Output (Y) = Σi (fuzzy outputi) × (Singleton posittion on x axisi) / Σi (fuzzy outputi)
For the example illustrated at right, the crisp output is:
(0) x (0) + (.25) x (30) + (.75) x (60) / 0 + .25 + .75 = 52.5
Note that you would intuitively expect the defuzzified output to be much closer to 60 than to 0.
Also note that the singleton defuzzification calculation is significantly less calculation-intensive than the method previously described.
μ
1 .75 .5 .25 0
0 30 60
= Center of Gravity
Defuzzification
Fuzzy Fundamentals Menu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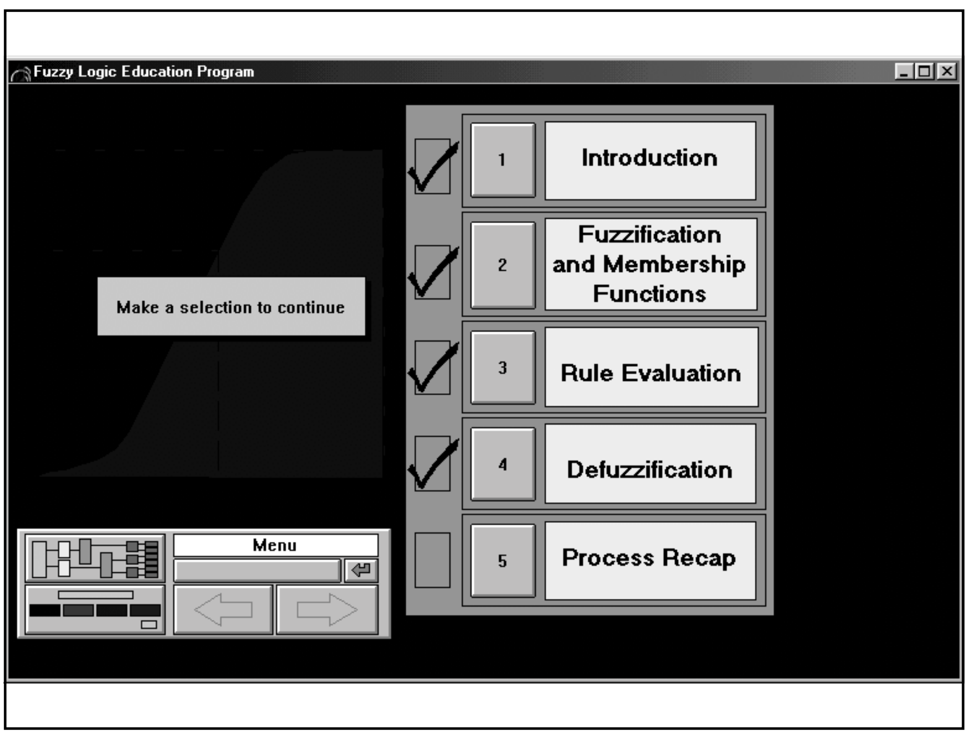
There are trade-offs in adopting regular fuzzy sets or singletons to represent an output variable.
During defuzzification using COG, the singletons require less computation, but the non-singleton sets may provide an output more consistent with your expectations for extraordinarily detailed control surfaces.
The methodology section of this course will present guidelines for choosing the appropriate defuzzification method for an application.
Common Defuzzification Methods
1) (COG) of arbitrary output membership functions.
2) (COG) of singleton output membership fuctions.
Defuzzification
Fuzzy Fundamentals Menu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