## **FLOWS: of Data vs Control**

Algorithms can be considered from two views both involving flows: data flow and control flow. Data flow emphasizes the flow of data objects, and control flow emphasizes the flow of control or actions. We will first consider data flows for a few pages and then control flows.

- Data Flow Diagrams (or DFDs) represent algorithms as machines or black boxes, with emphasis on the input-output data flow. This view is in direct contrast with flowcharts, which emphasize flow of control. Data flow diagrams describe mainly the function of an algorithm; what it does, rather than how it does it.
- Data Types describe the kind of data objects which are considered. It is not sufficient to say that the data are numbers. In computer science a big distinction is made between integers (or whole numbers) and real numbers (those with a decimal point). Integers and Reals are represented differently in computers. Integers arise from counting; Reals come from measuring. First we will consider Real numbers for a few pages and then Integers.
- **Real numbers** usually arise from measuring and are normally expressed with a decimal point such as 3.1415, 2.5 and 0.7. Sometimes they are expressing in a scientific or exponential notation, but that will be considered later.
- **Operations on Real numbers** are the four arithmetic functions shown in figure 1: addition, subtraction, multiplication and division. They are considered at a high level as indicating what they do and not how they do it. Later we consider how division is really done; now we use the division function to create larger functions. It often helps to hide details!
- Formulas, or arithmetic expressions, indicate how numbers are grouped and manipulated. Data flow diagrams show this structure of such formulas are given in figure 2. Each of the four arithmetic functions (addition, subtraction, multiplication and division) is viewed as a black box operator with two inputs and one output. The two values at the inputs are transformed by the operator into one value at the output. The "flow" of these values ultimately leads to one resulting output value at the bottom.
- **Precedence** is a common convention indicating that multiplication and division are done before addition and subtraction. For example, the formula

1 + 2\*3 should be evaluated as 1 + (2\*3) = 7 instead of (1+2)\*3=9 because multiplication is done before addition. When multiplication and division occur together in a term, it is evaluated from left to right as shown in figure 3.

- **CONVERT**ing data flow diagram of figure 3 converts 20 degrees C to 68 degrees F, and figure 4 converts this resulting 68 degrees F to 19.9999... degrees C. This illustrates a problem of possible inaccuracy when dealing with repeated unending decimals, such as 5/9 (or similarly 1/3).
- **POLYNOMIALS**, are formulas (arithmetic expressions) involving a single variable, say X, taken to various powers and multiplied by various coefficients in the form:

 $Y = A + B*X + C*X^2 + D*X^3 + E*X^4$ 

This polynomial can be factored to yield the formula:  $Y = A + X^{*}(B + X^{*}(C + X^{*}(D + X^{*}E)))$ 

The first way may seem more natural for humans, but it involves many more multiplications; the second way requires only 4 multiplications. The second, factored, method has a more "elegant" data flow structure which is shown in figure 5.