object until the end is overshot, and then backtrack one step to probe in smaller steps to locate the right-hand end of the object accurately. A suitable step-length is the distance between the two front sensors — around 60 mm ($2^3/_8$ in) — since this ensures that when an overshoot occurs, one sensor will still close.

The third stage involves a similar method of probing, but this time the robot moves to the left, counting the number of steps taken until the left-hand end is encountered. At the end of this stage, the length of the object side will be held in the count variable and can be PRINTed.

MEASUREMENT PROGRAM

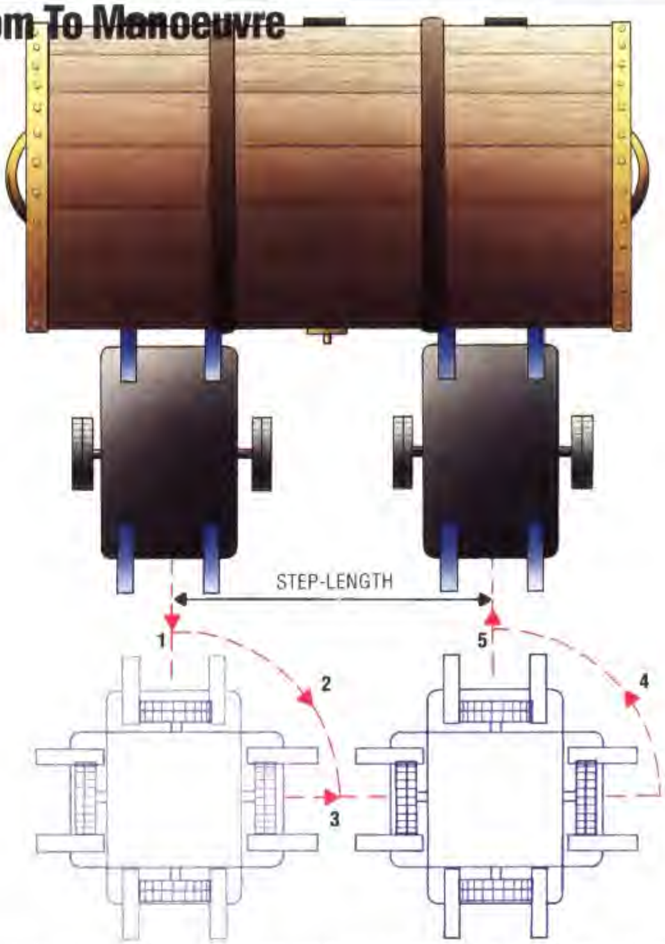
We give listings for the Commodore 64 and BBC Micro. The pulse/distance and pulse/angle ratios — found by experiment in the last instalment of the robot project (see page 894) — should be inserted for your own robot. The procedural nature of BBC BASIC is ideal for writing a program of this type. We can adopt a highly structured approach to the problem, controlling each movement made by the robot via separate procedures. Two features of BBC BASIC — extended variable names and parameter-passing between procedures — mean that the program can more closely resemble the way we think. The Commodore version can adopt the same structured approach, but notice how much more difficult structuring is in Commodore BASIC — the Commodore 64 program is much more difficult to follow than the BBC version.

Having isolated the main tasks that the program must perform, we can design individual procedures for moving the robot and combining a series of manoeuvres to create a 'probing' procedure. Combining probing procedures forms the overall 'measure' procedure. In this application, the different procedural levels are easily identified, ranging from a simple procedure to pulse the motors at the lowest level to the entire measuring activity at the highest.

Problems can arise if the robot is not initially positioned at exactly 90° to the object side to be measured. If only one sensor makes contact when both should, then the logic of the program will make the robot decide that it is positioned at one end of the object. If this happens then break into the program, align the robot perpendicular to the side to be measured, and run the program again from the beginning.

Several intrinsic measuring errors can be identified. The width of each sensor, for example, is around 5 mm ($^3/_{16}$ in). Locating the left- and right-hand ends of the object, therefore, can produce a total maximum error of 10 mm ($^3/_8$ in). In addition, when the robot accurately probes for the ends of the object, it does so in steps of 5 mm, and thus a further error of 10 mm can be introduced. When testing our prototype robot, the average error in measuring an object of side 410 mm (16 in) was around 20 mm ($^3/_4$ in) — an error of only five per cent.

Room To Manoeuvre

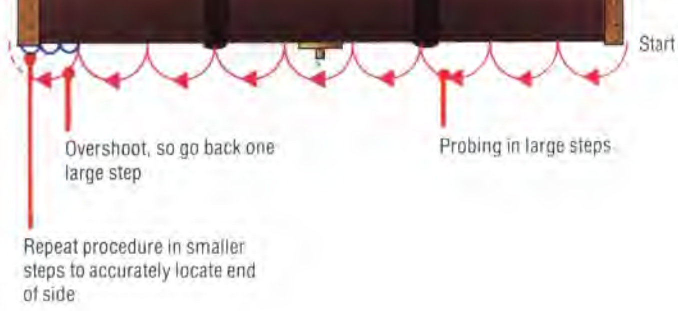


The figure above demonstrates the robot's basic probing manoeuvre. When both sensors are closed, the robot will reverse (1) to enable it to turn without colliding with the object.

The robot will then perform a 90° turn (2) and move forward the step-length (3). The robot performs another 90° turn so that it is once more facing the object (4), and finally moves forward (5) to test whether the object is still in front of it.

This process is repeated along the length of the object, as shown below. At first the robot takes a number of large steps, to gain an approximate length of the object. When only one, or neither, of the sensors is closed, the robot backtracks the last step, and repeats the whole probing procedure using smaller steps

Probing Procedure



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