Chapter 4

Induction, Recursion, and Recurrences

4.1 Mathematical Induction

Smallest Counter-Examples

In Section 3.3, we saw one way of proving statements about infinite universes: we considered a "generic" member of the universe and derived the desired statement about that generic member. When our universe is the universe of integers, or is in a one-to-one correspondence with the integers, there is a second technique we can use.

Recall our our proof of Euclid's Division Theorem (Theorem 2.12), which says that for each pair (m, n) of positive integers, there are nonnegative integers q and r such that $m = nq + r$ and $0 \leq r < n$. For the purpose of a proof by contradiction, we assumed that the statement was false. Then we said the following. "Among all pairs (m, n) that make it false, choose the smallest m that makes it false. We cannot have $m < n$ because then the statement would be true with $q = 0$ and $r = m$, and we cannot have $m = n$ because then the statement is true with $q = 1$ and $r = 0$. This means $m - n$ is a positive number smaller than m. We assumed that m was the smallest value that made the theorem false, and so the theorem must be true for the pair $(m - n, n)$. Therefore, there must exist a q' and r' such that

$$m - n = q'n + r', \text{ with } 0 \leq r' < n.$$

Thus $m = (q' + 1)n + r'$. Now, by setting $q = q' + 1$ and $r = r'$, we can satisfy the theorem for the pair (m, n), contradicting the assumption that the statement is false. Thus the only possibility is that the statement is true."

Focus on the sentences "This means $m - n$ is a positive number smaller than m. We assumed that m was the smallest value that made the theorem false, and so the theorem must be true for the pair $(m - n, n)$. Therefore, there must exist a q' and r' such that

$$m - n = q'n + r', \text{ with } 0 \leq r' < n.$$

Thus $m = (q' + 1)n + r'$." To analyze these sentences, let $p(m, n)$ denote the statement "there are nonnegative integers q and r with $0 \leq r < n$ such that $m = nq + r$" The quoted sentences

4 2 Recursion Recurrences And Induction

Rachel Sandford

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