Chapter 4
Metaheuristics in General

In Chapter 3, we pointed out different ways of conducting a heuristic search within a solution space based on the knapsack problem. We also pointed out that the basic principles of search heuristics which we identified, are generic, meaning that they can be applied to a whole variety of different optimization problems. Likewise, we can consider the strategies which build upon the basic principles as problem-independent. The actual realization of the basic principle itself, however, is a problem-specific issue, since it has to be defined how a solution may be constructed, modified or recombined. Figure 4.1 gives an illustration of these interrelationships.

This distinction between problem-independent and problem-specific aspects of search heuristics reveals a major advantage: The search strategies and the problem-specific parts can be implemented independently from each other. This means that

Fig. 4.1: Problem-independent and problem-specific aspects of search heuristics
it is possible to implement search strategies in a completely abstract way, like a framework. Later, when it comes to a concrete application, it is of course necessary to implement the problem-specific parts (e.g. a solution modification mechanism). But once this is done, they can typically easily be “plugged” into an already existing (search) framework and it is possible to run the associated strategies almost exactly the way we described them for the concrete example. Hence abstraction allows us to reuse components of search heuristics and may avoid that the respective method has to be implemented from scratch for each new problem. The abstract parts can be regarded as an upper or “meta”-level of a search heuristic, leading to the term “metaheuristic”, as first introduced by Glover in 1986 [91]. It is important to note that the pure presence of meta-concepts is not sufficient for a heuristic search method to be called a metaheuristic. Before we actually come to a definition of the term, we will first identify a further property which is commonly regarded as the key-feature of a metaheuristic.

So far we gave a taxonomy of search heuristics at the level of their basic principles. But what if we want to make an assessment at the strategy-level? Can we somehow rate the effectiveness of strategies in finding near-optimal solutions in short time? Are some strategies superior to others? This chapter deals with exactly those questions and provides an appropriate differentiation.

Let us motivate this point of view by means of an example: Remember the principle of search by solution modification (cf. Section 3.2). In this context we distinguished two kinds of derived search strategies:

• Strategies which only accept an improvement in solution quality at each iteration step
• Strategies which also permit deteriorations in some situations

As we have seen in the knapsack example, the latter one is obviously superior, because it enables the search process to escape from dead-ends and to possibly find even better solutions afterwards. The concept of selectively permitting deteriorations in solution quality can be seen as a key factor for “broadening” the search. Hence on the one hand we have search strategies which are very “simple” and straightforward and others which are more sophisticated by incorporating enhanced concepts. Indeed we are interested in the more sophisticated ones and we want to analyze them in a more detailed way. But at first, we have to generalize our considerations: Can we identify a criterion which is abstract enough to allow a similar classification also in the case of search by solution construction or recombination? The subsequent section provides an answer to this question, by describing important characteristics of effective search strategies in a general way.

4.1 Intensification and Diversification

Generally speaking, we clearly require a search heuristic for optimization problems to be goal-directed in the sense that it actually realizes an optimization process.