# A Motivated Definition of Exploitation and Exploration

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The terms exploration and exploitation are as old as evolutionary algorithms themselves, yet few papers are truly devoted to this subject. This study can be seen as an exercise in formal reasoning to provide a well-understood, unambiguous definition of the terms exploitation and exploration. We start from a simple algorithm framework and give clear definitions of exploitation and exploration in this context.

Implicitly associated with each element $s$ of the search space $S$ is a unique *representation* of this element. A *representation-related neighborhood* $N(s)$ is defined in each element as a probability distribution on the set $S$. With each element $s \in S$ we also associate an *objective value* $f(s) \in \mathbf{R}$. To give a non-trivial meaning to the terms exploration and exploitation, the fundamental assumption of black-box optimization has to be satisfied: there must exist a, possibly unknown yet exploitable, relationship between the neighborhood structure and the objective function. The algorithm framework is then defined as follows:

1. Choose an initial element $s^0 \in S$, and evaluate it to obtain $f(s^0)$. Initialize the step counter $i$ to 0.
2. If $f(s^i)$ satisfies the stopping criterion, stop the algorithm.
3. Using $s^i$, generate the neighborhood $N(s^i)$.
4. Construct a set $T \subset S$ by drawing elements from the distribution $N(s^i)$ and compute the objective values of the elements of $T$.
5. Given *only* $f(s^i)$ and $f(t)$ for all $t \in T$, select one element $t$ from $T \cup \{s^i\}$.
6. Accept $t$ as $s^{i+1}$, the next element of the algorithm.
7. Increase $i$, and go to step 2.

We believe that it is important to distinguish between representational and objective information. This distinction combined with the distinction exploration/exploitation leads us to four useful concepts defined by step 3 through 6 of our framework.

Step 3 is the explicit (representational) restriction of candidate successors to the neighborhood of the current element. Bearing in mind the fundamental assumption of black-box optimization, we postulate that this is exploitative: the representation of the current element is used to generate candidate successors. We call this **representational exploitation.**

The selection of the set $T$ in step 4, is a process which is independent of the representation and objective value of the candidates. Because *new* elements are evaluated, we postulate that this step is explorative: Since this exploration is restricted to the neighborhood, we call it **neighborhood exploration**.

In step 5, the information obtained by the neighborhood exploration is used to select a successor from the candidate elements. We postulate this to be exploitative, and we call this form of exploitation **objective exploitation**, since only objective information is used.

Step 6 is the acceptance of the selected element as the successor. It is postulated to be explorative, since it moves the algorithm from one known element to a (known element) with an unknown neighborhood. This action is called **generational exploration**.

A full report of this research, which also considers quantifications of exploitation and exploration, can be found in [1]. More complex algorithms (population-based, and/or featuring memory) will be considered in further contributions.

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## REFERENCES

[1] B. Naudts and C.A. Schippers. A motivated definition of exploitation and exploration. Technical Report 03/99, University of Antwerp, Belgium, 1999.