# Multi-Criteria Iterative Auctions Using Evolutionary Algorithms

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**Abstract**. Evolutionary algorithms help in performance of multi-criteria auctions. On these auctions bidders negotiate about commodity (product or service) described by a set of independent attributes. The evolutionary algorithms allow iterative negotiation of bidders, who has slightly different concepts in features of a finally negotiated contract (if they win the auction). The final set of attributes closing the auction is the best one the auctioneer can get from the present bidders. Equally the winning bidder has to fulfill conditions that are the best ones for him to offer to win the auction.

## Introduction

The business is based on transformation of accessible resources to commodities (products or services), which are required by consumers [10]. Many methods for redistribution of required resources and offered commodities exist. One of them is an auction. The multi-criteria auctions allow negotiating about many properties of individual components. If partners fiddle with contract conditions to adjust it to be acceptable for all of them the auction is iterative.

The multi-criteria iterative optimization is not a problem, which has not been solved before. It is known and studied in evolutionary computation (e.g. in [1,5,6]). We use the evolution algorithms for description of iterative multi-criteria auctions and their abilities.

## Auctions

Auction is chaired negotiation between sellers and buyers. It distributes resources according to actual demand and supply. Chairing role, the auctioneer, is usually played by a specialized subject.

In our work we consider only *1:m* and *n:1* relation auctions (explained below). This delimitation allow us to simplify terminology of auction participants to *auctioneer* who is present in one instance in the auction, and *bidders*, who are not limited in their number of individuals (this number cannot be negative). We do not distinguish classical and reverse auctions here because they vary only in the election of a reference commodity. The common reference commodity is money but monetary markets reduce its sense, and barter does not use it at all.

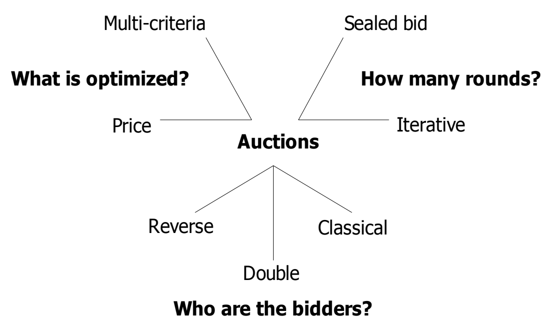


**Fig. 1.** Criteria for auctions categorization

## Categorization of auctions

Not only one type of auction exists [4]. Based on the works studying electronics auctions ([7,8,9,11]) we use 3 criteria distinguishing the various auctions (Fig. 1 shows them). They consider number of bidders, adaptation of proposed bids, and complexity of best bid evaluation. The main categorization of auction types according the criteria is: iterative auctions (Some of them are known as "Open-cry" auctions) and sealed-bid (one-bid) auctions. Auctions are further divided by number of sellers (*n*) and buyers (*m*) participating in auctions to *1:m* (and *n:1*) relation auctions and *n:m* relation. We consider only iterative auctions.

Iterative Auction is the auction where the auctioneer and bidders iteratively reduce conditions (e.g. price) they ask or offer to overbid their competitors. The seller and buyer, whose bids meet, win the auction by the offered conditions. We focus on iterative auctions because they allow auctioneer and bidders to determine contract conditions according to actual market situation, and all negotiation participants can influence and monitor their constitution.

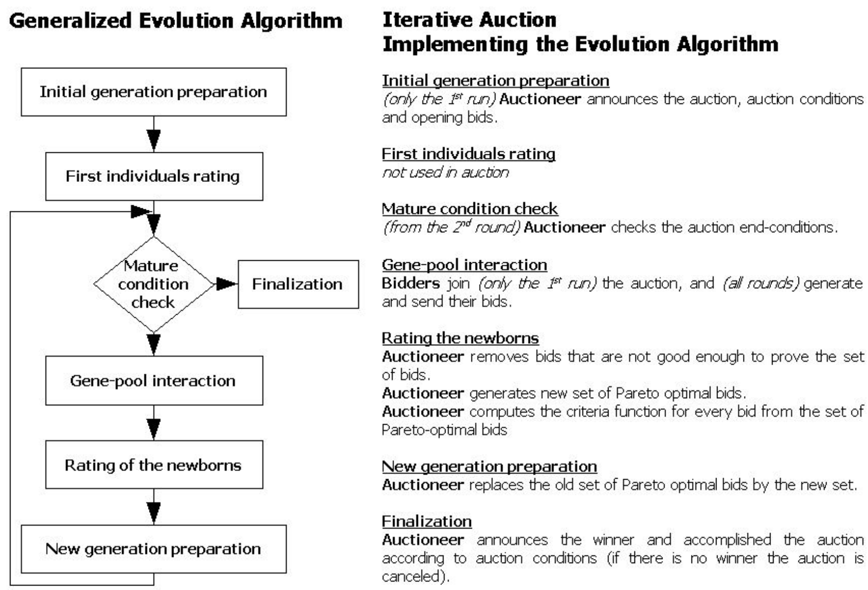


**Fig. 2.** Generalized evolution algorithm and iterative auction

## Multi-criteria auctions

The more complexity is in the trading, the higher sophistication of auction abilities is required. The commodities are not absolutely commensurately, and supply or demand of individual traders varies in details. It is why multi-criteria auctions are becoming significant. One of the most used accesses to multi-criteria decision process described e.g. in [2, 3, 12] is criteria function, which transforms several attributes to one virtual parameter. The bids are compared according to this parameter. To win the auction the bid must maximize this parameter.

## Evolution Algorithms

The generalized evolution algorithm described e.g. in [1, 5] iteratively creates individuals having required quality. The process is shown on the left part of the Fig.2. At the beginning the initial generation is prepared. Individuals from this generation are rated and checked if some of them fulfill requirements. If the one is found the algorithm ends, otherwise individuals from the actual generation can become parents for new individuals. They are put to gene pool to do it. The rating of newborns follows. After it selected newborns replace some of their parents. The other newborns and the replaced parents are spoiled. Formed group is the new generation that is checked for containing the required one, and if the one is not found this new generation creates another individuals later. Actual methods and conditions used in evolution algorithm vary in particular implementations.

## Multi-criteria auction described by evolution algorithm

Using generalized evolution algorithms to describe one criterion auction seems to be over-sophisticated because chromosome representing bid contains only one gene – the price. Evolution algorithms come in useful to understand multi-criteria auctions. In the multi-criteria auctions chromosomes represent particular bids and they contain genes describing independent attributes:

$$\vec{c} = [c_0, c_1, \dots c_n], \qquad \textbf{(1)}$$

where $\vec{c}$ is the chromosome containing $n$ valuated attributes of the bid.

Comparison of chromosomes to select the one representing the best bid is divided into two steps. The former one, based on single genes comparison, select the Pareto optimal set of bids. This set is primarily used for creating consequent generations of chromosomes. The latter step we call the rating. It becomes significant at the moment of finalization of generation creating to select the winner of the auction. The rating is provided by any criteria function [2, 3, 12].

Each gene from one chromosome can be compared to a relevant gene from any other chromosome to find the better one or they are alike:

$$\vec{c}_1 P_> \vec{c}_2 \Leftrightarrow (\forall i)(\exists j)(c_{1i} \geq c_{2i}, c_{1j} > c_{2j}), \qquad \textbf{(2)}$$

The relation $P_>$ is valid if chromosome $\mathbf{c}_1$ exceeds chromosome $\mathbf{c}_2$ by at least one gene and simultaneously it is not exceed in any gene. And:

$$\vec{c}_1 P_= \vec{c}_2 \Leftrightarrow (\forall i)(c_{1i} = c_{2i}) \qquad \textbf{(3)}$$

The relation $P_{=}$ is valid if chromosomes $\mathbf{c}_1$ and $\mathbf{c}_2$ in all genes. If none of $xP_{>}y$, $yP_{>}x$, or $xP_{=}y$ relation is true, then the chromosomes cannot be compared by these two relations. In this case they are Pareto optimal.

At the beginning the auctioneer generates Pareto optimal set of chromosomes, the initial generation $\mathbf{G}_0$. The set can contain more than one chromosome, where none of them exceeds another one in all genes:

$$G_0 = \{c : (\forall i)(\forall j) \neg (\vec{c}_i P_{>} \vec{c}_j \vee \vec{c}_i P_{=} \vec{c}_j)\}. \quad \mathbf{(4)}$$

The bidders in the gene pool create and submit chromosomes of their bids. Bidder bidding in auction submits one or more chromosomes that do not exceed one another in all genes (the bids from one bidders are Pareto optimal). Bidders that submit no bids give this auction up.

Permissible chromosome must exceed at least one chromosome from the generation released to the gene pool:

$$NB = \{c : (\forall \vec{x})(\vec{x} \in G_n) \neg (\vec{x} P_{>} \vec{c} \vee \vec{x} P_{=} \vec{c})\}, \quad \mathbf{(5)}$$

where **NB** is a set of accepted newborn bids' chromosomes, and $\mathbf{G}_n$ is the current generation of chromosomes released to the gene-pool before. The chromosomes contained in the **NB** set improve the Pareto optimal set and the auctioneer accepts it to cultivate the final contract conditions. Consecutively auctioneer rates the new chromosomes by criteria function to get the one number for each chromosome. Later, the auctioneer creates a new generation by selecting the best ones from the previous generation and new individuals.

$$G_{n+1} = C \cup NB\,, \quad \mathbf{(6)}$$

where

$$C = \{c : (\vec{c} \in G_n)(\forall \vec{x})(\vec{x} \in NB) \neg (\vec{x} P_{>} \vec{c})\}, \quad \mathbf{(7)}$$

The $\mathbf{G}_{n+1}$ is the new generation consisting of **C** – survived chromosomes from the previous generation, and **NB** – newborn ones.

Look through the individuals released to the gene pool every bidder can verify its bids was considered in selecting individuals to the just released generation.

During the auction the published results of the rating function are informative for bidders to help them in bidding. At the moment, when no bidder submits a chromosome proving the generation (no one overbid the announced conditions – e.g. price in one-criterion auction) the cultivation is finished. The rating function selects the best chromosome now. This one contains genes describing the bid conditions by that the auctioneer and the winning bidder conclude the contract.

## Conclusion

A particular approach to multi-criteria auctions has been proposed. It is based on evolutionary algorithms that provide iterative optimization of individuals described by set of attributes. Bidders are allowed to overbid others in the attributes they are good at, and they are not forced to prove attributes difficult for them. The bidder can win the auctions if another bidder does not overbid him in all attributes. Auctioneer keeps the power of a last verdict to decide the winner of the auction. However any last bidder standing in the auction is chosen to win, no one else can offer a bid that is better in any attribute without loosing in another one.

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