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## Implementation and testing of a genetic algorithm for a self-learning and automated parameterisation of an aerodynamic feeding system

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### Abstract

An active aerodynamic feeding system developed at the IPA offers a large potential regarding output rate, reliability and neutrality towards part geometries. In this paper, the procedure of a genetic algorithm's into the feeding system's control is shown. The genetic algorithm automatically identifies optimal values for the feeding system's parameters which need to be adjusted when setting up for new workpieces. The general functioning of the automatic parameter identification is confirmed during tests on the convergence behaviour of the genetic algorithm. Thereby, a trade-off between the adjustment time of the feeding system and the solution quality is revealed.

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### 1. Introduction

Innovative and flexible production processes are essential for the manufacture of customer-tailored products. One possibility for fulfilling these requirements is to design a self-optimising production [1]. For this reason, Park et al. utilise a conventional simulation on the basis of finite elements to improve production efficiency and to increase component quality during the manufacture of belt parts, and extended this with a self-optimising algorithm. Based on a practical example, they are able to show that the production efficiency can be increased by 30% due to the development of a system featuring self-optimisation [2].

This article focuses on the development of a self-optimising feeding system technology in automated assembly. This is of particular importance because it frequently represents a quality, time and costs bottleneck [3]. Due to the fact that feeding technology is also frequently slower than the process speeds of production and assembly systems, it can become the weak point of an entire production system [4]. This statement is confirmed through investigations which have shown that the overall availability of production and assembly systems is reduced as the number of feeding systems increase [5]. Moreover, in automated assembly, up to 75% of the

equipment costs are caused by feeding technology. Therefore, this area offers huge potential for rationalisation [6].

The majority of feeding systems used at present are vibratory bowl feeders [7]. The wide incidence can be explained by many advantages. These include a very simple and compact structure, low purchase costs, a low maintenance effort and their wide range of applications [5]. But due to their specific construction, the vibratory bowl feeder is hardly variant flexible. Often, flexibility can only be achieved by a change in baffles which causes long setup times [8]. Therefore, much research has been done to improve the vibratory bowl feeder's flexibility in the past. For example, easy changeable baffles have been designed [9]. Furthermore, workpiece-specific baffles were developed which can be coupled in any order within the vibratory bowl feeder [10]. But considering these achievements, either the setup procedure remained greatly time consuming or the vibratory bowl feeder became very susceptible to disturbances. A highly current approach is to divide the vibratory bowl feeder into modules with standardised interfaces which can be changed quickly and with little effort. However, this application is only economically feasible for a medium feeding performance [11]. An extremely flexible approach which promises short setup times is the use of feeding systems with optical workpiece

detection. But these systems are not yet capable of providing today's required feeding performances [12]. All in all, conventional feeding systems either offer limited process speed or they lack in variant flexibility.

Thus, in future, further development and the introduction of innovative, self-optimising feeding systems represent a major source of potential and a decisive success factor for rationalisation, flexibility and increases in the availability of production systems.

In the course of this investigation, an aerodynamic feeding system was developed at the Institute of Production and Logistics (IFA) at Leibniz Universität Hannover, in which the feeded workpieces are orientated using a homogenous air flow field. In this article, it is shown how the aerodynamic feeding system is developed into a self-optimising system using a genetic algorithm. Furthermore, the function and results of the self-parameterisation of the aerodynamic feed system are presented in a real operating situation.

## 2. Basic principles

### 2.1. Functional method of aerodynamic orientation

The functional method of the aerodynamic feeding system is presented in Figure 1. The process uses special air flows and the asymmetry of workpieces. Workpieces can be asymmetrical due to an eccentric centre of gravity or an asymmetrically projected form. The feeding system consists of a guide level vertically inclined in guide direction by the gradient angle  $\alpha$  and the inclination angle  $\beta$ , and a guide edge standing vertically on it.

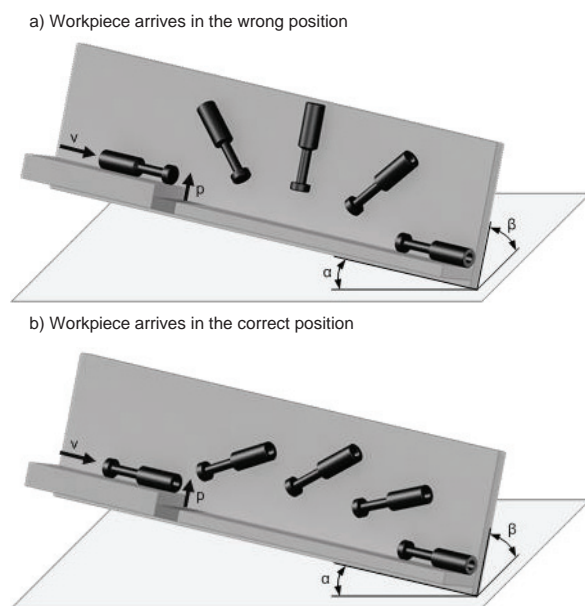


Fig. 1: Illustration of the aerodynamic orientation process

In the guide edge, there is an air nozzle which emits a constant vertical air flow with an adjustable air pressure  $p$ . The components to be orientated are individually separated in

an upstream vibratory bowl feeder and fed at a defined speed  $v$  via a guide level infed conveyor and, due to the inclinations, slide down the guide edge. As they pass the air nozzle, each workpiece is provided with a momentum which makes them turn. The feeding system must be adjusted in a way that the angular momentum is not sufficient to turn components which are already correctly orientated, but which is large enough to turn incorrectly orientated workpieces for correct orientation. The four parameters gradient angle  $\alpha$ , inclination angle  $\beta$ , the air pressure of the air nozzle  $p$  and the feeding velocity of the workpieces  $v$  are the parameters the system can be adjusted with in accordance to the workpieces being fed in. At the end of the sliding edge, a high-speed camera is mounted which checks the orientation of the workpieces.

The setting of the feeding system is limited to the adaption of these aforementioned parameters [13]. The determination of optimum parameter values for the achievement of a high orientation quality does however represent a highly time-consuming and work-intensive process. The same applies for the adaptation of the system settings for altered ambient conditions such as an altered ambient air pressure or humidity, which can influence the system characteristics through the open design of the feeding system. One highly-promising approach for the minimisation of the time and effort involved is the independent and self-optimising parameterisation [14]. For this reason, in prior research activities a genetic algorithm has been developed in Matlab which independently identifies the optimum values for the four operating parameters in a simulation model of the aerodynamic feed system.

### 2.2. Application of a genetic algorithm for aerodynamic orientation

In this section, the genetic algorithm of the aerodynamic orientation is briefly explained. A genetic algorithm has been chosen because it offers the possibility to evaluate generated solutions by means of the orientation rate. Furthermore, genetic algorithms investigate search spaces intelligently. This is necessary in the optimisation problem observed in this paper due to the high number of possible parameter configurations. Additionally, genetic algorithms offer the potential to simultaneously satisfy the two objectives of scanning the whole solution space while reducing the computational time [15] and have thus been successfully applied in many machine learning problems [16].

Genetic algorithms start with the initialisation of a start population, which consists of randomly generated chromosomes. After this, new generations are created in steps through the application of two operators: the crossover operator and the mutation. Whereas with the crossover so-called parent chromosomes are combined with each other to produce new chromosomes, with mutation only one element of a chromosome is locally modified. The selection of chromosomes for crossover and/or mutation processes is based on the fitness value or respectively on the suitability of the respective chromosome with regard to a preferably good solution of the optimisation problem.

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