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Development of a vision-based automatic vaccine injection system for flatfish

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ABSTRACT

Traditionally, flatfish vaccination has been performed manually a laborious and time-consuming, procedure with low accuracy. The handling requirement also makes it prone to contamination. With a view to eliminating these drawbacks, we designed an automatic vaccine system in which the injection is delivered by a Cartesian coordinate robot (also called a linear robot) guided by a vision system. The automatic vaccine injection system is driven by an injection site location algorithm that uses a template-matching technique. The proposed algorithm was designed to derive the time and possible angles of injection by comparing a search area with a template. The algorithm is able to vaccinate various sizes of flatfish, even when they are loaded at different angles. We validated the performance of the proposed algorithm by analyzing the injection error according to randomly generated loading angles. The proposed algorithm allowed an injection rate of 2000 per hour on average. Vaccination of flatfish with a body length of up to 500 mm was possible, even when the orientation of the fish was random. The injection errors in various sizes of flatfish were very small, ranging from 0 to 0.6 mm.

1. Introduction

Aquaculture is the fastest growing sector of agriculture in the world; it accounts for almost 50% of the world's food fish (FAO, 2008). Recent statistics released by the National Oceanic and Atmospheric Administration (NOAA, 2008) show that worldwide aquaculture production almost doubled between 1998 and 2007, with 50 million tons produced in 2007, compared to 28 million tons produced in 1998.

In parallel with this increase, the damage to hatchery fish has also become more extensive. In response, the world including South Korea is pursuing the development of vaccines for disease prevention (Afonso et al., 2005; Kim et al., 2009; Mutoloki et al., 2004). The vaccine market in South Korea had an annual budget of 1.8 billion KRW in 2008 and 3.2 billion KRW in 2010. This accounts for 2–3% of the international vaccine market and demonstrates its continuous growth. It is thus clear that the maintenance of a stable supply and the preservation of the health of aquaculture resources entail a growing demand for vaccination. In view of this growing demand the conventional vaccination method needs to be improved, so that a commercial application allowing rapid and accurate vaccination can be made available.

The vaccination of aqua-cultured organisms can be performed either manually or automatically. Manual injection requires the fish to be anesthetized prior to injection, and injection is usually achieved using an air-powered syringe. An accomplished individual is capable of injecting between 1000 and 1200 fish an hour in general (Ellis, 2002), and about 1000 fish an hour in the specific case of flatfish. Manual injection requires more highly trained staff than does an automatic vaccine injection system; therefore, manual injection is more costly.

In contrast, machines are now often used to vaccinate between 7000 and 9000 fish an hour, but they require fish to be of similar size and larger than those for manual injection (Plumb and Hanson, 2010). One of such automated systems is the AutoFish System (SV5). Developed by Northwest Marine Technology, Inc., it separates the fish by size and funnels them into a tube leading to an irrigation chamber, where the fish are injected and subsequently sent into a holding tank (Sharp, 2007). The AutoFish System (SV5) has the disadvantage of separating the fish by size before vaccination. Thus, the development of a more flexible automatic vaccine injection system is urgently required in order to reduce the cost and time of vaccination procedures while maximizing their effectiveness.

With this end in view, we developed an automatic vaccine injection system following an in-depth analysis of previous works on the development of such systems (Cobb, 1985; Kumar et al., 2003; Litte et al., 2007; Matsuoka et al., 2005; Pinkiewicz et al., 2011; Storbeck and Daan, 2001; Yang and Cho, 2000; Zappe et al., 2006).

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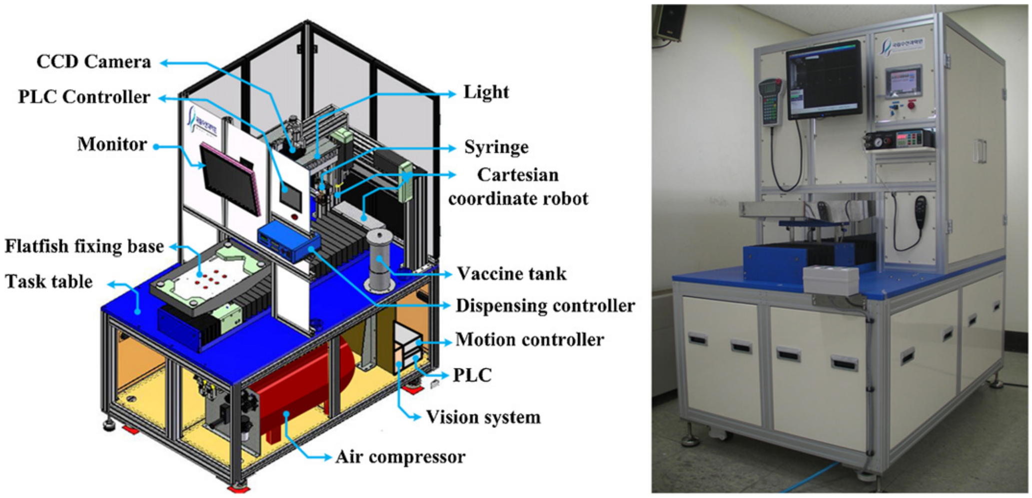

Fig. 1. Configuration of the automatic vaccine injection system for flatfish.

Our approach is based on principles of vision-based robotics and it uses the kind of mechanical system described by Cho and Shim (2004) and Kim et al. (2004) that employs controllers to carry out biological injection with the necessary force and at a suitable angle.

The automatic vaccine injection system for flatfish developed in this study is controlled by a specially designed automatic injection algorithm. Its main components are a vision unit that recognizes flatfish sizes, a Cartesian coordinate robot, a vaccinating device, and a flatfish fixing base. The proposed automatic injection algorithm improves the time needed to identify a vaccination site within the search area and is not affected by the rotational angle of the flatfish. It was designed to be able to vaccinate flatfish loaded randomly, irrespective of their size.

2. Materials and methods

2.1. Description of the automatic vaccine injection system for flatfish

Fig. 1 shows the layout of the various components of the automatic vaccine injection system: task table, flatfish fixing base, monitor showing injection process, programmable logic controller (PLC), change coupled device (CCD) camera, light, syringe, Cartesian coordinate robot, vaccination tank, dispensing controller, motion controller, vision system (PV 500, Panasonic), and air compressor. The system is capable of visually monitoring the injecting process and controlling the angle of the injection needle, the injection depth, and the vaccine dose. Table 1 lists the values of the vision system and CCD camera parameter set for the flatfish injection experiment.

2.2. Proposed automatic injection algorithm

Generally, the standard procedure for determining the injection site on a flatfish using the template matching tool provided by a conventional vision system, as shown in Fig. 2, involves the following: analysis of the size of a flatfish contained within the blue outline (template scope) relative to the green outline (search scope), comparison of the size with various stored sizes of flatfish, and finally, selection of most suitable template. However, as the vision system can only store a maximum of 16 templates, this may result in recognition error and a consequent lack of accuracy. The smaller the search scope, the less is the time needed to identify the injection site. However, when a flatfish is loaded with random orientation, the search scope needs to be widened to accommodate the rotation angle. In consequence, the time needed to locate the injection site is prolonged when larger rotation angles need to be accommodated.

Table 1
Values of the vision system and CCD camera parameter set.

CCD camera		Vision system	
Gain	Shutter speed	Inspection	Method
1	10 ms	±180°	Template matching

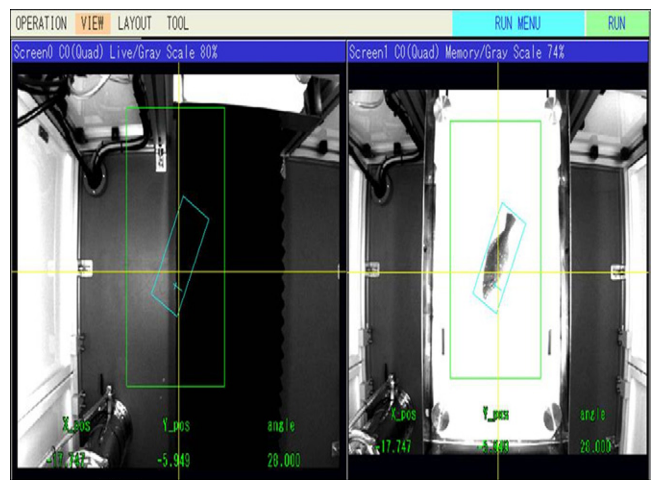

Fig. 2. Search scope (green line) and template (blue line) scope of the vision system.

Fig. 3 shows one approach to this problem. Using Eqs. (1) and (2), we can optimize the search scope area according to the rotation angle when a flatfish is loaded, effectively reducing the average time required to locate the injection site. Here, *TL* and *BW* denote the total length and the body width of the flatfish, respectively; *L* and *H* in Eq. (1) denote the width of the search scope and the length of the search scope (diagonal length of the template scope), respectively. *M* is the maximum distances of the template scope from the *y*-axes. The automatic injection algorithm is able to vaccinate when the conditions in Eqs. (1) and (2) are satisfied.

$$H = \sqrt{TL^2 + BW^2} \quad (1)$$