BJRS

BRAZILIAN JOURNAL
OF
RADIATION SCIENCES
09-01A (2021) 01-10

Improvement of an automatic seed implantation system for prostate brachytherapy with yz axis

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ABSTRACT

Brachytherapy is the use of radiation sources close to the site that needs treatment. It has become an extremely sought-after option by research fields for its impressive efficiency and practicality. In addition to being a fast-paced procedure, it allows patients to leave hospital care very soon after it is done, with minor discomfort, which can be considered an advantage. The prostate brachytherapy procedure is divided into two stages, obtaining images of the region where seed implantation will take place and the application itself. The images are obtained by ultrasonography, which will guide the insertion of the needle into the patient's body. The ultrasonography is made during the implantation. During the implantation, the patient is anesthetized and immobilized, so that movements that compromise the accuracy of the needle, which, by the current manual method, are already subject to oscillations are avoided. Breeding movement still present. Currently the implantation of radioactive seeds is done manually by a clinician who uses needles and monitors their positions through the images generated by ultrasound equipment. Thus, the main objective of this project was to improve the prototype of the Prostate Seed Implantation System (SISP), developed by the Nuclear Engineering Department of the UFMG (Nuclear Engineering Department). Thus, the device allows automated scanning on x, y and z axes, facilitating the application of radioactive seeds in prostate brachytherapy treatments, which in current treatments are done manually by the clinician. And the possibility of controlling this movement via *BLUETOOTH* technology.

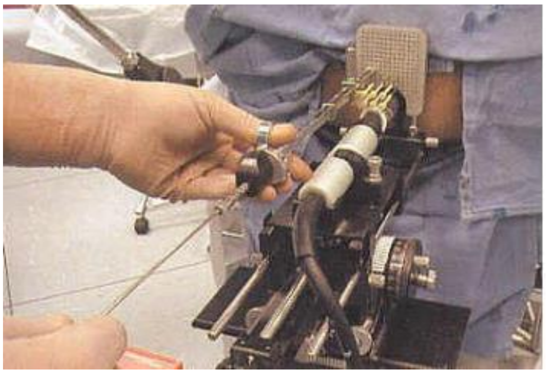
Keywords: Brachytherapy, implant automatic systems, radioactive seeds.

ISSN: 2319-0612
Accepted: 2020-07-20

1. INTRODUCTION

Brachytherapy in the treatment of prostate cancer has increased in recent years due to the high efficiency and relative convenience. In the last few years the use of iodine 125 has decreased in Brazil. The patient undergoes a single procedure, simple and outpatient procedure prevent hospitalization and allow a quick recover. The application of radioactive seeds is carried out in an unauthorized manner [1]. The Clinician mechanically applyes the needles with the radioactive seeds in a system that aids the placement of seeds in the patient's prostate, as shown in figure 1.

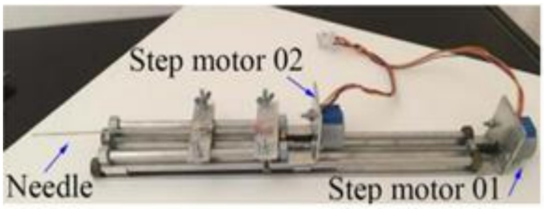
Figure 1: *Manual application of radioactive seeds [2].*



Source: [2]

Due to the amount of seeds to be inserted, this whole procedure becomes slow and tiring. This work will present the improvements made in um prototype using a stepper device called the Prostate Seed Implant System (PSIS). PSIS is a prototype that is under development at Universidade Federal de Minas Gerais - UFMG [3]. The PSIS prototype was built in 2017 and the system side views can be seen in figures 2a and 2b respectively.

Figure 2: *a) Image of the seed applicator. b) Lateral view of the PSI system.*



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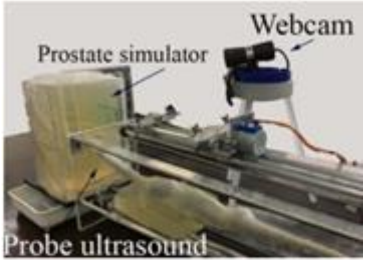


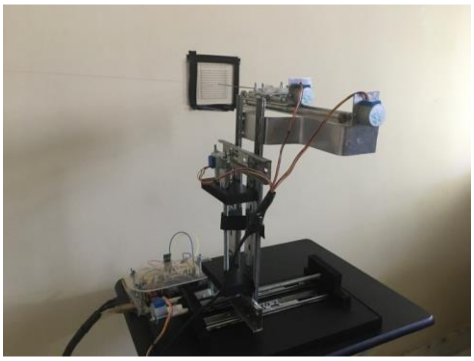
Source: Own authorship, (2019).

The PSIS is able to assist in the simulation of brachytherapy procedures, where implants of radioactive sources of iodine-125 and of ceramic seeds of Ho-166 will be performed in the future.

2. MATERIALS AND METHODS

Improvements to the prostate seed implant system (PSIS) occurred mainly in mechanical y and z sweep movement systems (left - right movement and vertical axis movement). The mechanical x-axis scanning system remained unchanged. In this way an x, y and z scan was achieved with the addition of some mechanical components. We can see a front view of the new prostate seed implant system (PSIS) in figure 3.

Figure 3: *Front view of new PSIS prototype.*



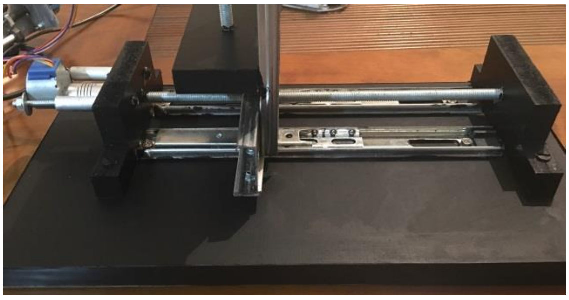
Source: Own authorship, (2019).

2.1 System design

2.1.1 Mechanical system

The base of the mechanical system is formed by a piece of wood of 350x180x20 mm. Two 250 mm sliding rails were fixed to this plate in parallel and 20 mm apart. Between the rails was a threaded shaft 80 mm in diameter and 25 mm in length. At one end of the threaded shaft was coupled a coupler and at the other end of the coupler was fixed to the stepper motor, as can be seen in figure 4.

Figure 4: *Top view of mechanical system base.*



Source: Own authorship, (2019).

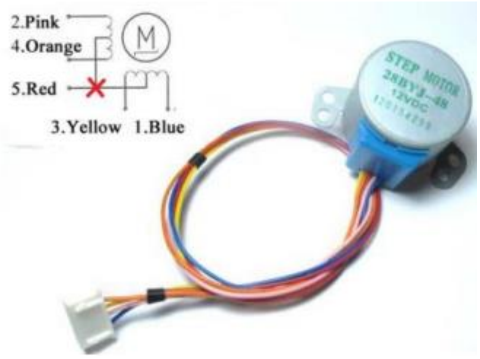
The movable part of the sliding axles was fixed to two other sliding rails in an upright position with the threaded shaft 80 mm in diameter and 120 mm in length. The fixing bases of the stepper motors were made of wood and the whole structure was fixed by screws

2.1.1 Stepper motors

Two stepper motors, 28BYJ48-12, modified from unipolar to bipolar, were added to the PSIS. This modification was made to enable steppper motor 28BYJ48-12 to work with microstepping motor driver A4988. As modified the x,y and z scan stepper motors in the original design [4]. The

28BYJ48-12 stepper motor has a high torque due to the reduction gear set internally [5]. In figure 4 we can see the designer of the stepper motor used.

Figure 5: *Stepper motor 28BYJ48 -12 set to bipolar mode*

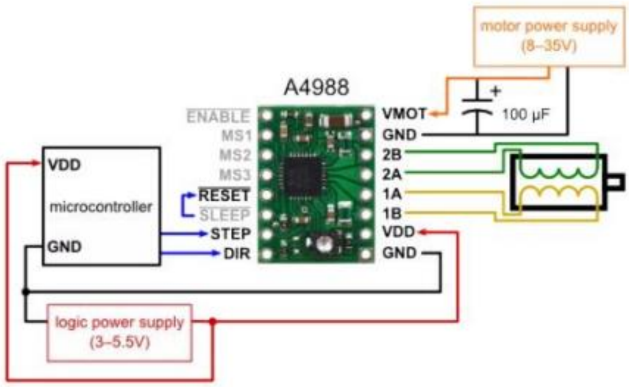


Source: [4].

2.1.2 Microstepping motor driver - A4988

A4988 is a complete microstepping motor driver with built-in translator for easy operation. It is designed to operate bipolar stepper motor with an output drive capacity of up to 35 V and ±2A. A4988 includes a fixed off-time current regulator which has the ability to operate in slow or mixed decay modes. Inputting one pulse on the step input drives the motor one microstep. There are no phase sequence tables, or complex interface stop program [6]. Two more microstepping motor driver-A4988 was used in the project, one for each stepper motor added. Totaling, in the project, four microstepping motor driver - A4988, connected as described in figure 4.

Figure 6: *A4988 simplified diagram (microstepping driver with translator and overcurrent protection)[4].*



Source: [4].

2.1.3 Arduino mega 2560 – microcontroller board

The arduino mega 2560 was maintained as the microcontroller responsible for the drive processing of the microstepping motor driver-A4988 which controls all psis stepper motors.

This device has the advantages of allowing programming in C/C++ language through an integral development environment (IDE) written in java with multiple libraries that facilitates these schedules [6].

2.1.4 The development of the graphical user interface - (GUI)

The main change made in the graphical interface was the change of programming language. The previous graphical interface was programmed in *MATLAB*®. The current interface was programmed in the python programming language in conjunction with tkinter. The tkinter library is responsible for creating a graphical environment on systems programmed in the python language [7].

An application has also been programmed for mobile phones with android operating systems. For the programming of this interface was used the appinventor 2, platform of the company *GOOGLE* [8]. This app has the same features as the graphical interface mentioned above.

2.1.5 Prototype activation via bluetooth technology

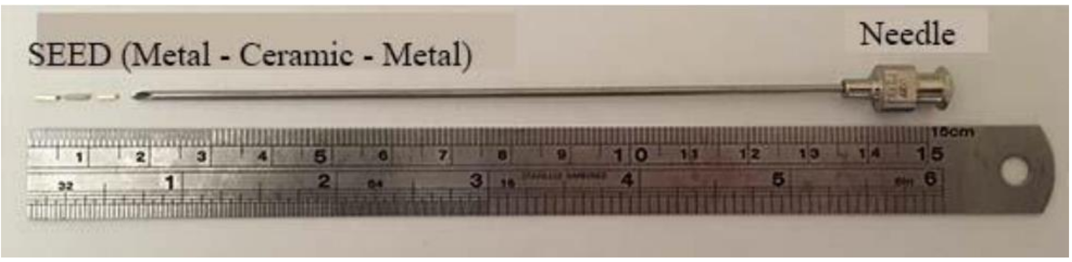
Another significant change in psis was the possibility of activation via *BLUETOOTH*. This remote actuation can be done by computer and by android smartphone. To make drive via bluetooth possible, the HC-06 module has been added to the *Arduino Mega* 2560.

2.1.6 Needle for application of radioactive seeds

A longer needle has been designed to allow for greater reach when applying seeds inside the prostate. the needle previously used was a commercial needle. the new needle was designed using two rods of wire, one hollow and one solid, of small thickness and 250 mm in length. in figure 7a we can see the measurements of the needle used previously and in figure 7b we have the designer of the new needle designed for the application of radioactive seeds to the entire internal area of the prostate.

Figure 7: *a) Needle used in the original prototype psis[2]. b) Needle designed for the new prototype PSIS.*

a)



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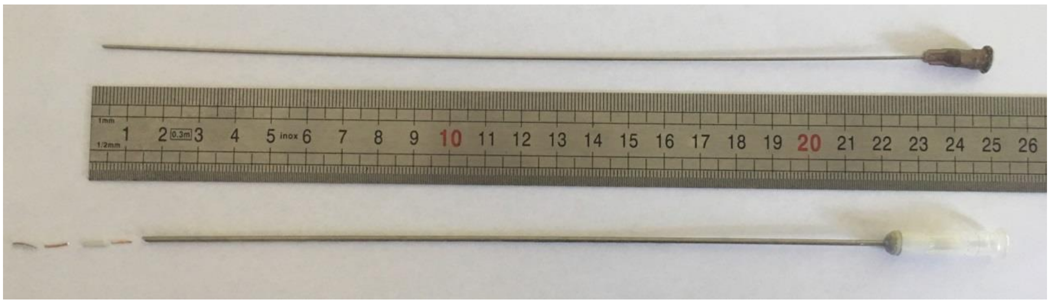

Source: Own authorship, (2019).

3. RESULTS AND DISCUSSION

The first positioning test with the new prototype was carried out with the aid of an acrylic jig plate with holes 5 mm apart in a straight line. Mates were easily achieved because the accuracy of the stepper motors used in conjunction with the threaded shaft pitches is less than 0.05 mm.

The original design needle, which was 130 mm long, had a poor range in practice. Thus, with this new needle length, 250 mm, it is possible to reach the entire internal area of the prostate, and it is also possible to supply the needle with a larger amount of radioactive seeds.

The main gain in changing the graphical user interface (GUI) programming language was the need for no license to use, which is required when using the *MATLAB*® program, since the program is commercial. This makes the prototype cheaper and capable of running on multiple platforms, such as computers running Windows, Mac and Linux.

The use of *BLUETOOTH* technology in the prototype enabled greater mobility in the application process of radioactive seeds. And greater radioactive safety, since the seed application professional can control the application from a distance.

4. CONCLUSION

The PSIS system improvement has been very satisfactory. This shows that it is possible to automate the application of radioactive seeds in prostate cancer treatments. The system cost is relatively low. The total project cost was less than U$150. Other studies and tests are underway.

Future enhancements to PSIS will be testing for resolution, precision and accuracy of radioactive seed applications and the creation of an implant protocol.

ACKNOWLEDGMENT

The authors thank the financial support of the National Council for Scientific and Technological Development - CNPq [456719/2013-0 REBRAT-SUS]. The design and the construction of the prototype of an automatic radioactive seed implantation system (PSIS) were performed in the Nuclear Engineering Department of the Federal University of Minas Gerais. The authors are thankful to all the researchers of the NRI – Núcleo de Radiações Ionizantes research group from the Department of Nuclear Engineering - UFMG who directly or indirectly contributed to the conclusion of this project.

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