AI-Enhanced Soccer-Ball

1. **Abstract:**

[a] This project proposes a cost-efficient AI-enhanced soccer training kit that consists of a soccer ball with sensors and a neural-network-based system implemented on an FPGA board. The sports industry has a growing interest in applying artificial intelligence (AI) to training plans, especially in soccer, since soccer exercises now rely on lots of performance-related data [1]. [b] Without smart data, soccer teams usually struggle to utilize the full capacity of the players’ skills. In addition to that, giving the players the wrong set of training exercises can cause injuries. [c] With a neural network system implemented on an FPGA and sensors placed inside the soccer ball, this product collects performance data of a player, creates a model for the playing style, and gives feedback on how to improve in training through a web page and mobile application. With data on each players’ performance, the training efficiency increases as each player knows what to work on, and the teams can put stronger playing strategies. [d] The AI-enhanced soccer-ball system is useful and applicable in all sports that use a ball just by modifying the ball and the data collected by the AI system.

[e] **Keywords** – AI, Soccer, FPGA, Neural Networks, Microcontrollers, Sensors

1. **Executive Summary:**

[f] This product aims to use artificial intelligence to improve the soccer industry by helping more people interested in soccer to enter the sport and improve on their own, in addition to using the popularity of soccer worldwide to grow the revenues coming from this industry. Artificial intelligence is the branch of computer science that involves building computer systems that learn from data and make decisions without the help of human intelligence. [g] Unlike in Europe, the soccer industry in the US is still struggling due to the lack of enough world-class professional trainers due to their high salaries. Consequently, the US men’s national soccer team and clubs have shown weak performances in international tournaments like the 2018 world cup qualifications [2]. On the women’s national team’s side, despite their outstanding performance by winning the last world cup tournament, the popularity of this sport among females is still low since most available soccer trainers at schools focus on male players. As a result, revenues of the US national soccer teams collectively have seen a significant decrease from $46.45 million in 2016 to $25.03 million in 2018 [3]. So, this project can improve the current situation by compensating for the lack of enough professional coaches and increasing the youth’s interest in soccer.

[h] This training kit is both affordable for the customer and profitable for Xilinx. The proposed project consists of a regular soccer ball with sensors and an FPGA board, which are components that cost about $200, which is a more affordable option to the player compared to a trainer who takes $25 per hour per person on average. Also, using only one FPGA board, which is the most expensive component in the system, a group of players can train in the same field and have the FPGA board present a visual model for each player on a regular computer. The initial cost of designing the system is high, but due to the number of soccer fans in the world that are in millions, the profit from selling this product is expected to cover the initial expenses in one year. [i] During the design phase, this system can start by studying a few performance metrics of players with different skill levels in one club as a trial. Also, the design engineers can use data sets from professional players for the initial training of the neural network system before publicizing the product. Once proven successful, the system can keep growing by improving the performance models, and more clubs, in addition to non-professionals, can start using the system worldwide. This product is a promising opportunity for Xilinx to gain shares in the AI market since the computational power of FPGAs is relevant for large AI applications.

1. **Product Description:**

[j] The main component of the project is the smart soccer ball with different sensors placed inside of it to collect and transmit various types of data. Accelerometers measure the acceleration of the ball that can represent the force by which the player kicks the ball, gyroscopes measure the angular velocity that describes how well the player’s aiming is, and GPS sensors provide the location of the player in the field during his motion. A small microcontroller board, along with a Wi-Fi module and a small USB battery, sends the data from the ball to the FPGA board through Wi-Fi. With all the sensors and the board inside the ball, the ball acts as a transmitter continuously sending out data.

The microcontroller inside the soccer ball acts as the brain that connects the sensors and controls the data flow between the sensors and the Wi-Fi module. The suggested microcontroller is a tiny Arduino chip called “Adafruit Trinket” since it is as small as a quarter of a dollar coin, and its weight does not affect the total weight of the ball [4]. Using a small printed circuit board (PCB), the microcontroller can connect to the sensors on one side of the PCB, and a USB battery and a Wi-Fi chip module on the other side. The suggested Wi-Fi chip is called “ESP8266,” which is light, low cost, and low power also [5]. In order to protect these electronic components from breaking, a durable light-weight material wraps the electronic components at the center of the ball in a structure that distributes the force from the impact of a kick over the surface of the ball. So, with the microcontroller as the brain at the center, the structure surrounding the microcontroller acts as the skeleton and skin that protect the brain.

The second part of the training kit is a “PYNQ” FPGA board connected to a typical computer. The PYNQ board is a platform that allows software developers to efficiently design complex systems using the Python programming language on Xilinx’s ZYNQ system-on-chip (SOC) device [6]. The PYNQ board can carry the AI system that collects data continuously to create a model for the player and compare it to models of professional soccer athletes. With the difference between the player’s performance and a professional player as a reference, the system generates feedback on the areas that need improvements. Since the PYNQ FPGA board has a feature that facilitates its connection to the internet, the AI system can display the data on a website and a mobile app. The mobile app displays the data in a graphical form to show where the weaknesses are and how the player has improved with time. Also, the PYNQ board can use a USB memory card that stores the chronological improvements over time. This whole system is compact, as the PYNQ board is small enough to be carried inside a pocket.

[k] For data processing and learning, the AI system utilizes a neural network architecture. A neural network consists of artificial neurons, which receive the continuous stream of data and process it based on a non-linear function with specific weights. The idea of the neural network is to have layers of the artificial neurons that adapt their weights based on the input data to produce a model for the player’s playing style. The process of weight adaptation of the neurons is the basis for the learning process in a machine learning system. Building these artificial neurons require flexible electronic circuits with high computational power and speed, thus using a high-performance FPGA like the PYNQ chip is a well-advised solution.

1. **Market Research:**

The soccer market has grown strongly and is a profitable industry to enter because, according to FIFA, there are 3.5 billion soccer fans and 265 million active professional players around the world [7][8]. Fans around the world spend millions of dollars on attending matches, buying club merchandise, meeting professional players, and practicing the sport itself. In the US, the interest of soccer has gone up despite the decline that this industry’s revenues have seen in the past few years. As a result, the United States Soccer Federation (USSF) is building new soccer stadiums, including new teams in the US soccer league like FC Cincinnati, and bringing professional players from top leagues like Wayne Rooney and Zlatan Ibrahimovic to play in US teams [9]. By collaborating with sports companies like Adidas, Nike, and Puma, this product can reach millions of people around the world and in the US. Major soccer events are held every year in every country, which are also opportunities to advertise for this affordable training kit. With this product, Xilinx can open a new segment of customers in its approach to marketing for its board’s AI capabilities.

Since soccer teams rely on performance data to devise their playing strategies, coaches and trainers are starting to consider AI solutions and are working with engineers to build smart tools to use the team’s data efficiently. One example is the Leatherhead soccer team, who used the IBM Watson AI software system to train its players and was able to go up 12 positions in the league [10]. Also, in May 2018, FIFA allowed soccer teams to bring devices to the soccer field for data collection and to use the analyzed information while the match is still going on [11]. For that reason, major soccer clubs approach companies like Olocip and SciSports that use artificial intelligence to ask for tools that the team can use to analyze live data [12]. So, soon, all soccer teams will rely on AI-generated data that will shape the structure of the whole soccer game.

In addition to the proposed idea of using data coming from sensors to feed the AI system, the other familiar approach in applying AI in soccer is to use visual data. For example, a team at Washington University, along with engineers from Facebook and Google, created a program that uses soccer footage to generate a 3D model of the match [13]. Also, a team from the ETRI lab in Korea developed a smart vision system using high-speed cameras placed around the field that can track the ball [14]. Although these AI systems show promising potential for soccer training, they face challenges in environments where something can hinder the vision like in the case of rain, snow, or if another player blocks the camera’s view.

One of the smart products that use visual data is Dribbleup’s smart ball [15]. This product includes a soccer ball and a stand to put the mobile phone on. Using an application downloaded on the phone, the camera of the phone tracks the ball during training. The limitation this product has is that the ball must always be in front of the camera and within a certain distance. So, Dribbleup’s smart ball is useful for simple exercises like dribbling or passing the ball.

Another smart product developed for soccer is Adidas’s miCoach ball [16]. This smart ball uses sensors inside the ball like the ones in the proposed project to send data to a mobile phone with a dedicated application installed on it. However, unlike the proposed product, miCoach ball does not create a model of the player’s style and only gives certain information based on the type of exercise selected on the mobile app. Consequently, players can use Adidas’s ball during practice, but not during a match. On the other hand, the proposed product provides broader training area coverage, in addition to processing the performance-related data instead of giving it in its raw state to the user.

1. **Finance and Economics:**

In this project, only the initial cost of designing the AI system and the ball is high, but the expected volume of customers willing to buy this product is enormous. The development phase requires at least five to seven dedicated engineers, whose salaries range between $100K and $180K per year, to work full-time on this project before selling the product. Also, the project needs a 3D printer and the material used for testing the internal structure of the ball. The project only requires one FPGA since the FPGA is reprogrammable, so the designers can modify the design as much as they require before reaching the final version of the product. So, the initial cost is around $1 million that includes the salaries of the team members and the materials needed for the project, and the time frame for the development phase is one year.

The expected return-over-investment for this product is high, since the demand for AI-based solutions in soccer is currently high, especially in elite professional clubs [17]. Xilinx can have two versions of the product; one version is an affordable kit for fans and amateurs and another sophisticated version for professional clubs. With advertising that the training kit is affordable after the product is out, Xilinx can sell this product to millions of fans around the world. In the US, there are about 24 million soccer fans, so assuming Xilinx sells this training kit to 1 million in the US in the first year, the profits can surpass the initial capital cost within a one-year timeframe. For professional clubs, Xilinx can provide a costlier training kit with extra sophisticated features like hardware security based on cryptographic infrastructure to protect the players’ data. In addition to that, feedback from clubs and players will require Xilinx to keep improving the system and providing technical support for the following years.

1. **Management Team:**

Designing the smart ball with sensors inside requires mainly engineers with electrical and mechanical backgrounds. Electrical engineers are responsible for designing the microcontroller and its connections with the sensors and the Wi-Fi module. Designing the microcontroller and its peripherals involves writing the program that manages the data received from each sensor before going to the Wi-Fi module and planning out how to place and connect all the sensors on the PCB board. For the internal structure of the ball, mechanical and materials engineers need to choose the right design and material. The internal structure is light, so the user will not feel the difference between the smart ball and a regular ball, and impact-absorbent to protect the inner parts of the ball.

The team working on the AI system is responsible for two parts, the neural network built on the FPGA for data analysis and the website that gives a visual model of the player’s performance. Digital design engineers with a background in FPGA design, along with AI and machine learning engineers, need to understand the types of received data sets to build a suitable neural network. The software engineers’ role is to design the visual display of the analyzed data for the user to observe on a website or a mobile phone app. This project also needs the help of soccer experts and well-known players to try out the system and give feedback during the development phase, making this project a fun collaboration between engineers and soccer athletes.

1. **Risks:**

Some risks exist that could affect the performance of the smart ball system like the sensors breaking inside the ball or having weak Wi-Fi coverage in the area. The design of the infrastructure of the ball requires it to be light, in addition to being capable of distributing the force applied to the ball equally around the surface, thus minimizing the impact energy reaching the sensors. Also, the chosen material of the infrastructure is an impact-absorbent material to add extra protection to the sensors. For areas that have weak Wi-Fi coverage, the designers can modify the system to transmit the data using Bluetooth instead. So, with careful design, the engineers can diminish the risks affecting the transmitting ball and tailor the product to suit the customer’s environment.

There is also a security risk where rival teams can collect the performance data since the AI system continuously receives data through Wi-Fi. On the transmitter side, the engineers can design the microcontroller to send encoded data that only a specific FPGA kit can decode. The AI system has the advantage of depending on an FPGA device, so in addition to data encoding, the design engineers can implement hardware cryptography algorithms that keep the information collected by the AI system safe. The PYNQ FPGA kit has portable memory modules that can store the statistics offline. Also, software cryptography can provide an extra security level to the information when displayed on the website and the mobile app. Thus, using the hardware and software flexibilities of the system, Xilinx is able to provide the security design support to the soccer club that requires additional security measures.

1. **Conclusion:**

[l] This project proposes a useful training system that utilizes artificial intelligence to help build stronger soccer teams and players with only a ball enclosing some sensors and an FPGA board. It presents a solution for soccer players to improve further and gets the youth interested in sports at a low cost. With customized design, the product holds the information on each player safely, preventing any leakage of data. This product is an opportunity for Xilinx to expand its share in both the AI market and the sports industry. The concept applied in this project manifests the AI’s significance in using data to improve people’s health and ameliorate people’s experience in sports.

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**Abstract & Executive Summary Checklist**

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| --- | --- |
| **Item** | **CHECKLIST ITEM** |
| [a] | Abstract: Motivation Sentence |
| [b] | Abstract: Problem Statement |
| [c] | Abstract: Results Sentence |
| [d] | Abstract: Conclusions Sentence |
| [e] | Abstract: Keywords |
| [f] | Executive Summary:  Proposal Background |
| [g] | Executive Summary: Problem Statement |
| [h] | Executive Summary: Financial statement related to the proposal |
| [i] | Executive Summary: Recommended action for “boss” |
| [j] | Product Description: Product Description (underline all sentences that apply) |
| [k] | Product Description:  Product Differentiators (what is “special” about the proposed product? |
| [l] | Conclusion:   Recommendation Statement |

**EE295 Grammar Checklist**

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| --- | --- | --- |
| **Item** | **Description** | **Compliance** |
| 1 | No personal words | Checked |
| 2 | No redundant phrases like “nothing but” or “very very” | Checked |
| 3 | No passive voice | Checked |
| 4 | All paragraphs with at least 3 sentences | Checked |