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IoT-Based Smart Fishing Gear for Sustainability of the Tanzania Blue Economy

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ABSTRACT

The fishing industry engages many Tanzanians and is among the leading sectors of Blue Economy in the country. However, fishing practices are small-scale with poor and insufficient number of fishing facilities, hence limiting productivity and efficacy. Studies argue that the low level of technology currently used in the country could possibly be an impeding factor. Specifically, fishers use non-interactive gears that cannot instantaneously update status and alert them whenever the gears are ready for collection. In such scenarios, fishers not only waste their time but also scarce resources such as fuel to facilitate trips to and from the fishing sites to check status of the gears. Thus, the application of Information and Communication Technology (ICT) could improve the production and lower operational costs is hypothesized. ICT solutions can help realize the processes with minimum human interventions while adding intelligence to the systems to make informed decisions and hence improve systems' efficiency. In this work, an IoT based smart fishing gear that counts and records the number of fishes in the gear and then displays them on a mobile application is proposed. The system can send alerts to the user when the required number of fish is attained, and provides navigation support to localize the distant filled gears. Results show that the system can send the location of a given gear and timely update the number of catches via the mobile application.

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INTRODUCTION

The earth's surface occupies a large percentage of water bodies (U.S. Geological Survey, 2019), making an effective use of this natural resource a viable strategy for socio-economic development . The strategy introduces the concept of Blue Economy that simultaneously encourages social inclusion, environmental sustainability, strengthening of maritime ecosystems, transparent governance and economic development (Spamer, 2015).

Blue economy offers diverse components, including, but not limited to, fisheries, tourism, maritime transport, marine biotechnology and bioprospecting, offshore renewable energy, seabed extractive activities, and aquaculture. These Blue Economy resources, collectively called blue resources, should be utilized sustainably while creating job opportunities and improving livelihood of people. Both ecological and chemical conditions of the resources must be closely monitored (Semboja, 2021; Slay & Dalvit, 2008).

Recently, Tanzania has taken a promising trajectory to exploit blue resources as an attempt for socio-economic development. Commending these efforts by the government, a paucity of studies on the application of Information and Communication Technologies (ICTs) in positively revolutionizing the fisheries industry is noted. Consequently, small-scale and artisanal fishers that are generally vulnerable to challenges and tragedies remain in unfavorable living standards. Therefore, guided by the Five-Year National Development Plan 2021/2022 – 2025/2026 (FYDP III)[1], advanced research should be conducted to address the fishers' challenges, including loss of fishing vessels and lives, unforeseeable changes of weather conditions, small fishing vessels with short fishing trips around the offshore, and ineffective techniques for predicting fishing sites. These challenges obscure the efforts to achieve the intended results of the FYDP III. Nevertheless, the vision and strategies stipulated in the FYDP III suggest an encouraging roadmap for the country to seize opportunities available from the blue resources and accelerate her socio-economic development (Okitasari & Katramiz, 2022). With the recent advances in ICT, specifically electronic sensors and Internet of Things (IoT), properly blending the techno power can maximize the economic impact of blue resources.

The Tanzanian government has been transforming ICT infrastructures to expand access to social and economic services. In achieving her grand ICT vision, Tanzania established the National ICT Broadband Backbone (NICTBB) that facilitates fast and reliable Internet connectivity through fiber cable. The NICTBB is sought to enhance digitization of government services: e-government, e-learning, e-health, and e-commerce, and support for ICT related research and innovations (Sedoyeka & Sicilima, 2016). Evidently, proper exploitation of ICT can definitely influence productivity and lower operational costs, an advantage that can strengthen our economy and increase employment opportunities in the country (URT, 2021).

In Tanzania, fisheries engage a large number of indigenous in fishing and other related activities (e.g., boat construction, fish vending and processing, and net mending), making it a leading blue economy sector. However, insufficient number and poor fishing facilities limit productivity of the sector and its contribution to the country's economy (Hamidu, 2012; Spiezia, 2011). It is hypothesized that digitization of the fisheries business processes may improve productivity and lower operational costs significantly.

In realizing the processes, ICT solutions can introduce intelligence to the fishing facilities and minimize human interventions, save time, and increase efficiency. The facilities (electronic systems) could then help authorities make informed decisions from data collected and analyzed by the systems.

In developed counties, ICT has received wide attention to digitize the Blue Economy. For example, in the recent international events by the *European Industry Days 2021* and the *European Maritime Day 2022,* scholars raised important discussions and proposed ICT solutions on the digital transformation and sustainability of Blue Economy for green recovery. Despite the efforts, the issue of introducing ICT into the fishing facilities, specifically fishing gears, remains an open-ended research problem (Takagi, Shimizu, Korte, & Suzuki, 2007; Xin et al., 2019). The concern seems more challenging in most developing countries, including Tanzania, striving to embrace ICT across various sectors of economy. Considering the determination of the Tanzanian government to achieve a sustainable Blue Economy, a need for coordinated efforts from research institutions to apply ICT for advancing this industry is mandatory.

[1] https://www.tro.go.tz/

This work considers the ICT solution for the traditional fishing gears, currently operated manually by our local and artisanal fishers. These gears are usually positioned based on the fishers' experiences and without tracking systems (electronic sensors), putting such gears at a risk of being lost. Besides, because the gears cannot communicate their catch status to the fishers, it becomes rather challenging to accurately predict the time that the gears, loaded with fish, should be collected. Challenged by the situation, IoT system that counts the instantaneous number of fishes in the gears and displays them on a mobile application is highly needed. The system can send alerts to the fishers when the predefined number of fishes is attained, and can provide navigation support to localize the distant filled gear. Our major research question was *how can ICT improve efficacy of the small-scale and artisanal fishers in Tanzania*?

METHODS AND MATERIALS

Artisanal Fisheries in Tanzania

The marine internal and territorial waters in Tanzania is estimated to cover 64,000 square kilometers (Hamidu, 2012). Broadly, the Tanzania fisheries are categorized into two groups, artisanal and commercial. The artisanal fishery comprises catch from both inland and marine waters and it lands most of the inland and the marine catches. The catch comprises a variety of finfish and invertebrates (Hamidu, 2012). Commercial fishery is exercised in both territorial sea and Exclusive Economic Zone (EEZ). In territorial sea, it mainly comprises prawns, lobsters, octopuses, and, to a small extent, sea cucumber while EEZ includes tunas, marlins, swordfish, mackerels and sardines. This zone, which is estimated to span 223,000 square kilometers, is mainly exploited by foreign fishing vessels (Hamidu, 2012).

Most artisanal catches are consumed locally while catches of nile perch, shrimps, lobsters, and octopuses are exported (Hamidu, 2012). In Tanzania, the marine fishery is concentrated in inshore waters whereby fishing activities are conducted within inner sea or internal waters within the 12 nautical miles (Hamidu, 2012). Fish traders visit different fish landing sites to buy and then transport fish to the markets across the country. Normally, the price depends much on the fish demand and location of markets (Sobo, 2013).

Small-scale or artisanal fisheries grew rapidly through export markets, adopting new technologies such as echo sounders and satellite positioning systems. In some developing countries, including Tanzania, artisanal fisheries suffer from lack of data and understanding on real trends and socio-economic impact (Hamidu, 2012). Even in countries with developed fisheries infrastructure, the management of the artisanal fishery relies on conventional methods where human activities are managed to maximize fisheries production, economic benefits, employment and national revenues. The conventional approaches, however, disregard broader effects of fishing activities on the environment, the effect of other non-fisheries related human activities, the ecosystem approach, and rights-based management (Hamidu, 2012).

With the advancement in ICT, specifically IoT technology, the fishery sector can be reinvigorated to harness ICT capabilities in improving the efficacy and productivity of the sector. The main contribution of this paper is the development of the IoT-based smart fishing gear which can constantly monitor the fish status and communicate important information and alerts.

Proposed IoT-based smart fishing gear embedded hardware

Development of the smart fishing gear followed a modified version of the Waterfall model (Figure 1). This methodology, unlike several others in the literature, offers quicker implementation with compelling results as the developer can separately evaluate each stage. Firstly, the authors conceived an idea to develop an IoT based smart fishing gear that facilitates fish harvesting. The conceived idea was realized as a block diagram (Figure 2) that demonstrates interconnections of various sub-systems. Secondly, the software and hardware specifications of the system was collected and established. In the hardware development, for instance, current-voltage and frequency requirements were established. Thirdly, the authors designed and simulated electronics circuits of the system using the Proteus software. This stage was followed by implementation and testing of the system.

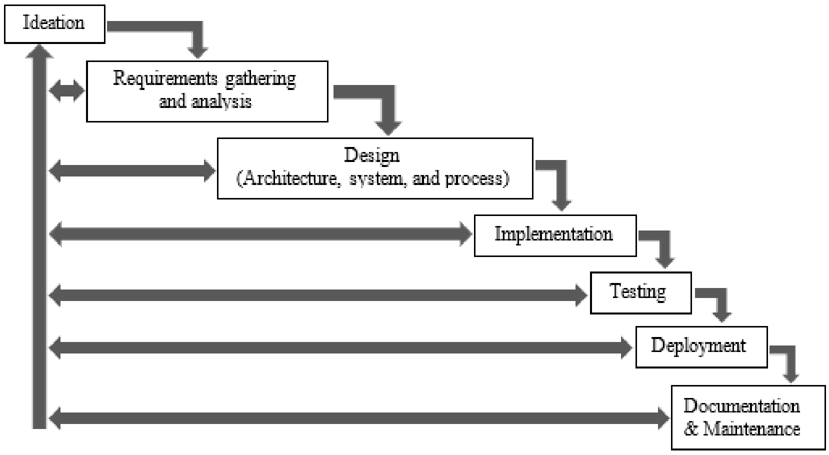


Figure 1. Modified waterfall model.

The proposed smart system (Figures 2 and 3) is composed of the sensor array, embedded controller, GPS [2] and GSM [3] modules, database and mobile application. The system can track the location of the gear and count the number of fishes entering the gear. The control unit receives data from sonar and location sensors. The data is then transmitted to the GSM module (model SIM800L) that provides 3G connectivity for a short message, SMS. The data containing gear identification number, location coordinates and number of fishes transmitted by the GSM module are stored in the database. The GSM module can, in addition, notify the fisher, through SMS, when the specified number of fishes is detected. At any time, users can view the status of the gears via a mobile application.

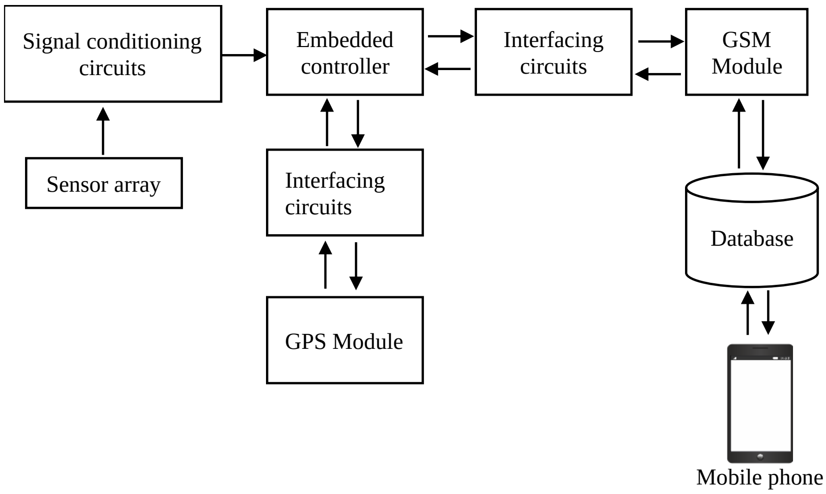


Figure 2: Block diagram of the IoT based smart fishing gear.

[2] Global Positioning System

[3] Global System for Mobile Communication

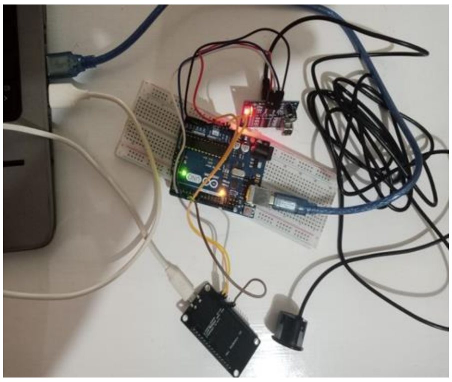


Figure 1: Hardware of the proposed system.

System Software

Functional requirements

The system functional requirements (Table 1) include functions and core operations of the system. These requirements can be implemented as a single system feature and form the basis of the whole hardware and software development processes. The requirements were obtained through literature review, observations and interviews.

Table 1: Functional requirements of the proposed system

Ref. No	Functional Description		Category
F1	*Management of User*		
	F1.1	User should be able to register in the system	Evident
	F1.2	System should allow user to enter their details (name, mobile number)	Evident
	F1.3	The system should be able to save the entered details in the database	Hidden
	F1.4	The user should be able to login in the system by providing their credentials	Evident
	F1.5	The system should be able to validate the login credentials	Hidden
	Management of Fishing Gear		
F2	F2.1	The system should show the number of fish gears owned by user	Evident
	F2.2	System should allow the user to specify the maximum number of fish in one gear	Evident
	F2.3	The system should be able to show the increment of number of fish in the gear	Evident
	F2.4	The system should be able to send the SMS when the specified maximum amount is meet	Hidden
	F2.5	The system should be able to show the exact location of fishing gear	Evident
	F2.6	The system should be able to record the type and number of fish in a given gear	Evident
	F2.7	The system should be able to print reports with filters capabilities	Evident

Mobile application

The mobile application, designed using Visual Studio, can fetch data from the database and display gear parameters to the user. The database of the system was implemented using phpMyAdmin, a MySQL database management system. The system operates as a mobile application on all android phones that support modern technologies.

Figure summarizes the proposed system use cases. Each user must log in to access the system features. There is no exception, hence the system administrator has to log in to the system to perform the stated tasks. All users of the system have a common login page, and only authorized and registered users can login into the system. The administrator interface consists of a linked navigation bar where user details can be viewed and a sidebar where each functionality of the administrator can be accessed. The administrator can register the fishers' name, mobile number and gear identification number, and can also view all registered fishers and edit or delete their details.

Users logged into the system can view locations and number of fishes in the gears (Figure (a)). They can, in addition, set the maximum number of fishes that the gears should collect for the system to notify the fisherman (Figure (b)).

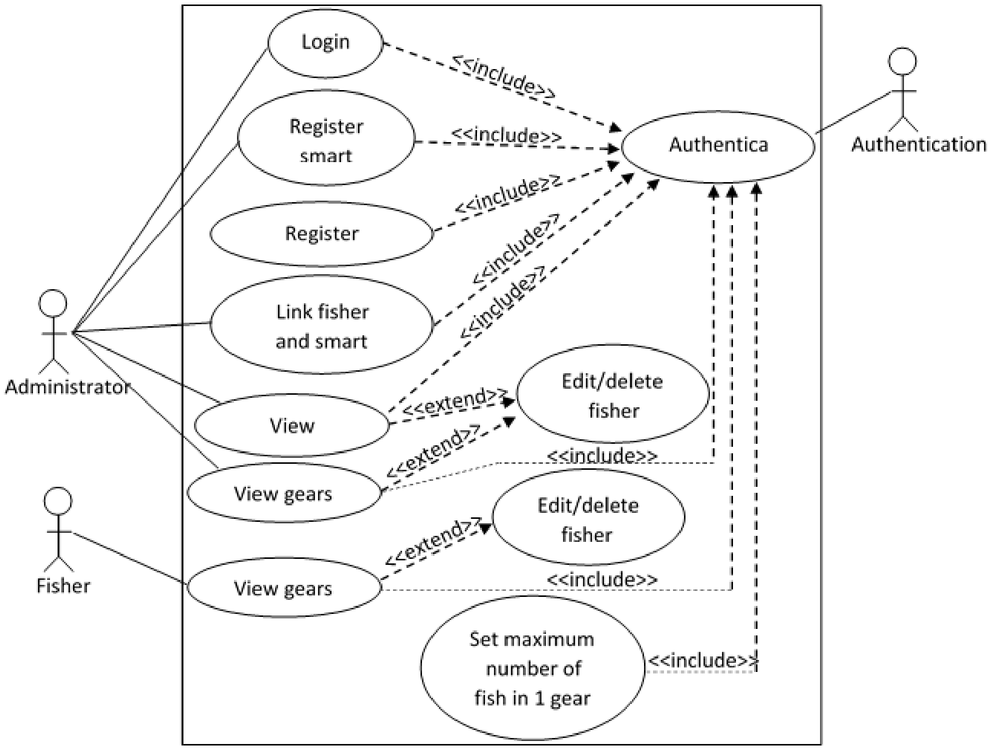


Figure 4: Use case diagram of the proposed smart fishing gear.

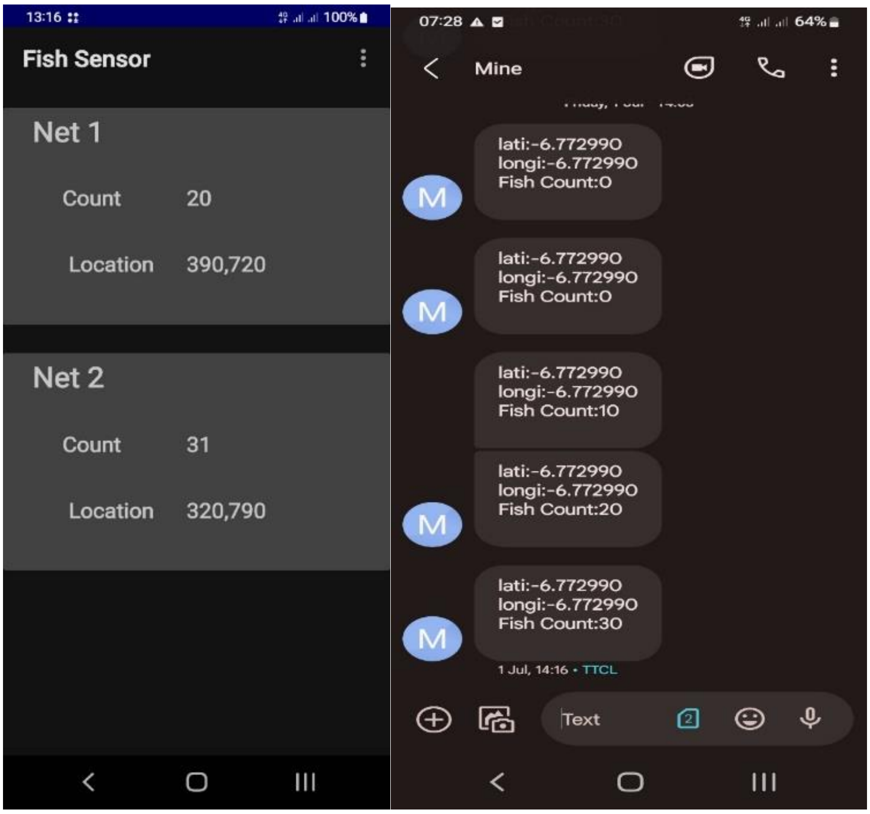
RESULTS AND DISCUSSIONS

The developed system generates three types of data: identity of the fishing gears, location, and number of fish caches. All these data are displayed on the mobile phone after being measured by the sensors and transmitted over a GSM network to the user. This information may either be requested by the user or pops up on the mobile application as an alert. Figure 5(a) shows the results obtained from two fishing gears containing 20 and 31 fish catches. Sample SMS notifications from a given gear is shown in Figure 5(b). Data from the mobile application can also be displayed on the website[4], developed to allow flexibility in data visualization. When the system is connected, the website collects data from the sensors in a real-time.

Our results provide some insights on the possibility to apply ICT as an enabling tool to improve the fishing industry, hence advancing the Blue Economy. Guided by the

[4] http://nazra.skyiottanzania.com/

Blue Economy policy of the country[5], it is recommended more innovative approaches to digitize this important sector. Moreover, coordinated efforts and strategic plans to foster the development of Blue Economy is needed. The government should bring together research institutions, stakeholders, and private sectors to contribute in nurturing the Blue Economy. The government may need to support ongoing initiatives from ICT institutions where researchers have demonstrated the potential of digital technologies in the sustainability of the Blue Economy. Also, funding organizations may capitalize on the wealth of local intellectuals to ensure that they generate practical ICT solutions for the Blue Economy. It is also observed that, there is limited funding in the area of ICT to support blue economy.



(a) Location and number of fish catch (b) SMS alerts

Figure 5: Mobile application of IoT based smart gear.

CONCLUSION AND RECOMMENDATIONS

In this paper, an IoT-based smart fishing gear for small-scale and artisanal fishers to accelerate and sustain the Tanzania Blue Economy is developed. The system may reduce the operational cost significantly and also improve the effectiveness of the fishing industry by supporting small-scale fishers. Results show that the system can send the location of a given gear and update the number of catches via a mobile application. Besides, the system can send notifications once the target number of fishes in the gear is attained. Currently, the possibility of using Long Range (LoRa) IoT technology to facilitate data transmission to further reduce

[5]https://www.fao.org/faolex/results/details/en/c/LEX-FAOC208265/

system cost is extensively being explored. Additionally, we intend to deploy the system into the real fishing sites to collect more data for research purposes, hence developing effective strategies for monitoring operations of the system.

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