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AN AUTOMATED, PREDICTIVE INFANT'S GROWTH AND NUTRITION MONITORING SYSTEM THROUGH IOT

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ABSTRACT: With the progress of information technology and the prevalence of smartphones, an opportunity to improve the children health services has been arisen. In this regard, many applications have been developed, most of which are not comprehensive enough to meet all of the needs in taking care of children. Maintaining the right balance in food intake is very important, especially in infants where tremendous growth occurs. Unlike adults, infants require someone's assistance in their food intake. In the modern world, where most of the infants are being sent to daycare, an automated food monitoring system helps in keeping track of their food intake. In this paper an automated food monitoring system with predictions to help a balanced meal is proposed. This sensor system consists of a piezo-based sensor board which can help in analyzing the weight of each meal and a smart phone camera to obtain nutrition facts of the ingredients. Hence, this model performs better results interms of efficiency, accuracy and recall.

KEYWORDS: Internet of Things (IoT), Smart Healthcare, Smart Home, Optical Character Recognition

I. INTRODUCTION

Early years of life of children are regarded as the golden period, which is the ideal time when children form their future habits. If an infant's health is impaired in the early years, it will usually last a lifetime. Thus, infants' growth should be monitored to detect and modify any deviations from the appropriate growth standard. Growth refers to specific body changes and increases in the child's size including height, weight, head circumference, and body mass index. Growth monitoring determines the desirability of infants' growth. The main aim of growth monitoring is the early detection of growth disorders.

Various factors can result in the deviation from the desirable growth[1]. The most important factor is nutrition, which provides the necessary energy for different activities and helps the body to avoid diseases. It can also prevent the prevalence of chronic diseases or reduce their intensity. Near 25 to 50% of infants have nutritional disorders. In this regard, there are some concerns about low weight gain, obesity, essential nutrient deficiency, and poor dietary variety. Malnutrition and stunting show the interrelated relationship. Stunting in children is the impact of nutrient deficiency during the first thousand days of their lives.

Stunting is a state of height index according to age below minus two standard deviations based on WHO standards. Stunting is the longterm manifestation influenced by a low-quality diet, recurring infectious disease, and environment. Based on the background, this article is aimed at designing research to monitor baby growth by implementing a database-system. The use of database-system will allow wider data service in the future: e-cloud. In general, designing a system to integrate with Android-based baby growth monitoring system, especially to identify the children's nutritional status based on body weight for age (BB/U), bodyweight for body height (BB/TB), and body height for age (TB/U).

According to previous studies, the majority of mothers do not have the necessary knowledge about the appropriate nutrition for their infants. Pathogens are another important factors influencing a child's growth. Regular vaccination can immunize a child's body against pathogens. However, some mothers have difficulty in remembering the vaccination dates of

ISSN PRINT 2319 1775 Online 2320 7876
Research paper Volume 11, Iss 9, 2022

their children, and some others do not have enough information about necessary care for the prevention of diseases or childcare at the time of a disease. In this regard, a standard continuous visit schedule is used to assess the infants' health and growth. In these visits, the infants' growth is measured and disorders regarding the growth curves are evaluated. Besides, the nutrition status and manner, vaccination, illness symptom, history of illness, as well as hearing, vision, oral and dental status are monitored [2].

Finally, the infants are screened for specific diseases such as autism. The main challenge with this program is that parents may find it difficult to have access to the doctor and treatment centers whenever they have questions or concerns about their infants. This challenge is more evident for parents living in remote rural areas.

Therefore, the issue of this study is to build a smartphone-based system that can reduce the difficulty of in-person referrals, establish a suitable collaboration between the physician and parents, and provide the ability to monitor growth, health and nutrition at any time and place. Smartphones have overcome the portability constraint of personal computer systems and provided access to health information in anywhere and at any time. Therefore, nowadays they have become a popular and powerful platform for developing mobile health [3]. Mobile health (m-health) services lead to the early prediction and management of every abnormality or disorder. In addition, using pervasive computing in healthcare systems reduces costs and improves services for patients. Besides, doctors and nurses become enabled to monitor and take care of patients in anywhere and at any time.

In pervasive computing, applications adapt their behaviors with contextual information and act, accordingly [4]. Context is a type of information that can be used to characterize the situation of an entity (such as a person, place or object). Combining m-health services with context-awareness increases their usefulness and popularity. However, mobile devices still have difficulty in running huge software programs. Transferring all or part of the processing and storage operations to the cloud is an appropriate solution to this problem. Actually, the advantages of cloud computing such as platform flexibility, interoperability, and providing on-demand services have made it the perfect solution for data integration as well as pervasive health monitoring. Leveraging new technologies in childcare can have a significant effect on their appropriate growth.

Several research studies have presented m-health systems for childcare. However, the majority of them are not based on the state-of-the-art scientific references. Besides, the quality of information provided by commercial m-health applications is often rated as quite poor. Moreover, the majority of designed systems do not meet all parental needs in a way that parents have to use several applications, simultaneously, to fulfil their requirements. For example, some applications only deal with malnutrition, some with obesity and overweight, and so on. This paper proposes an infant growth monitoring system, based on the well-known scientific references in this area. The proposed system, which consists of parental as well as physician sides, provides three major functionalities including child growth and nutrition monitoring, child health monitoring, and doctor intervention capabilities [5].

The context-awareness technology is used to make the system intelligent and predictor so that suitable services can be provided by modeling the current situation. Furthermore, cloud computing is employed to resolve the low computing power and storage shortage issues of smartphones. The system is implemented by Java-based Android programming language for

ISSN PRINT 2319 1775 Online 2320 7876
Research paper Volume 11, Iss 9, 2022

Android-based mobile phones. It is evaluated using the Software Architecture Analysis Method (SAAM). The results indicate that PIG is more comprehensive than other similar systems and bears more functional capabilities.

II. LITERATURE SURVEY

H. Kalantarian, N. Alshurafa and M. Sarrafzadeh, et.al [6] Maintaining appropriate levels of food intake anddeveloping regularity in eating habits is crucial to weight lossand the preservation of a healthy lifestyle. Moreover, maintainingawareness of one's own eating habits is an important steptowards portion control and ultimately, weight loss. Though manysolutions have been proposed in the area of physical activitymonitoring, few works attempt to monitor an individual's foodintake by means of a noninvasive, wearable platform. In thispaper, we introduce a novel nutrition-intake monitoring systembased around a wearable, mobile, wireless-enabled necklacefeaturing an embedded piezoelectric sensor. We also propose aframework capable of estimating volume of meals, identifyinglong-term trends in eating habits, and providing classificationbetween solid foods and liquids with an F-Measure of 85% and86% respectively. The data is presented to the user in the formof a mobile application.

L. I. Octovia *et al*., [7] described Information and communication technologies (ICTs), such as computer, mobile phone, and internet, are emerged as an accelerator in the health sector development. They can play a critical role in pursuing outcome for most vulnerable groups, such as pregnant woman and children in developing countries. In this paper, we review the use of m-Health to improve mother and child health. We use the result of this review to propose a design for a set of m-Health applications focused on the improvement of mother and child nutrition in Indonesia. Our analysis of existing applications includes both a literature review and an empirical search of publicly available mobile apps from Google Search, Google Play, and Apple Store. From the review, we found that there exist several mobile and or e-Health systems focusing in improving early life nutrition delivery, both state and privately made. In Indonesia specifically, the Minister of Health has launched a mobile app for early life to work in conjunction an established monitoring book of mother and child health "Buku Kesehatan Ibu dan Anak". However, the download rate of this app remains low. This result produced important information that can be further learned, so we could set and deliver a successful humanitarian technology implementation in improving early life nutrition care in Indonesia.

N. Hezarjaribi, C. A. Reynolds, D. T. Miller, N. Chaytor and H. Ghasemzadeh,et.al [8] propose development and validation of Speech-to-Nutrient-Information (S2NI), a comprehensive nutrition monitoring system that combines speech processing, natural language processing, and text mining in a unified platform to extract nutrient information such as calorie intake from spoken data. After converting the voice data to text, we identify food name and portion size information within the text. We then develop a tiered matching algorithm to search the food name in our nutrition database and to accurately compute calorie intake. Due to its pervasive nature and ease of use, S2NI enables users to report their diet routine more frequently and at anytime through their smartphone. We evaluate S2NI using real data collected with 10 participants. Our experimental results show that S2NI achieves 80.6% accuracy in computing calorie intake.

P. Sundaravadivel, K. Kesavan, L. Kesavan, S. P. Mohanty and E. Kougianos, et.al [9]presents a new Internet of Things (IoT)-based fully automated nutrition monitoring

ISSN PRINT 2319 1775 Online 2320 7876
Research paper Volume 11, Iss 9, 2022

system, called Smart-Log, to advance the state-of-art in smart healthcare. For the realization of Smart-Log, a novel 5-layer perceptron neural network and a Bayesian network-based accurate meal prediction algorithm are presented in this paper. Smart-Log is prototyped as a consumer electronics product which consists of WiFi enabled sensors for food nutrition quantification, and a smart phone application that collects nutritional facts of the food ingredients. The Smart-Log prototype uses an open IoT platform for data analytics and storage. Experimental results consisting of 8172 food items for 1000 meals show that the prediction accuracy of Smart-Log is 98.6%. A correct balance of nutrient intake is very important, particularly in infants. When the body is deprived of essential nutrients, it can lead to serious disease and organ deterioration which can cause serious health issues in adulthood. Automated monitoring of the nutritional content of food provided to infants, not only at home but also in daycare facilities, is essential for their healthy development.

A. Doulah, X. Yang, J. Parton, J. A. Higgins, M. A. McCrory and E. Sazonov, et.al [10] described field of sensor-based dietary assessment and behavioral monitoring is rapidly expanding. New devices and methods for detection for food intake and characterization of ingestive behavior, energy intake and nutrition have been introduced. Quite often the testing of new devices is limited to restricted meals in laboratory setting, which has the advantage of being controlled, but may not be representative of real life conditions. To illustrate the importance of field testing, we performed a statistical comparison of meal microstructure metrics acquired in laboratory versus a field-like study. In the laboratory study, individual participants ate a self-selected meal in isolation.
In the field-like study, participants consumed selfselected meals in a social setting. In both studies, the participants were monitored by both video observation and wearable food intake sensors. Statistically significant differences were observed in the duration of the meals, duration of ingestion, number of bouts of ingestion, duration of pauses between ingestive bouts, number of bites and other metrics. These results suggest that field testing presents a far different picture of ingestion process and therefore is needed for any realistic assessment of the monitoring devices.

S. Malik and S. -H. Park, et.al [11] intended for use by patients who are using various health promotion systems in homes, fitness centers and hospitals, for exercise and nutrition control. Before and after use, these patients need some common platform to communicate with these systems and their respective medical experts for various information needs. They also need some easy way for continuous feedback on their health status, counseling and motivation for adherence to their respective health promotion program. From the perspective of a medical expert, they need an efficient way of monitoring their patients, and delivering timely feedback and advice to them. Information systems of concerned centers need to have timely information of every stage of a complete study starting from patient's reservation to their results delivery. In this paper we present a ubiquitous health promotion system (uHPS) that can address issues spanning multiple areas of health promotion, and it includes diverse kinds of equipments which might be geographically distributed.

Y. J. Thong, T. Nguyen, Q. Zhang, M. Karunanithi and L. Yu ., et.al [12] propose a novel approach on measuring food nutrition facts, through a pocket-size non-intrusive near-infrared (NIR) scanner. We build efficient regression models that can make quantitative prediction on food nutrition contents, such as energy and carbohydrate. Our extensive experiments on off-the-shelf liquid foods demonstrates the accuracy of these regression models and proves the applicability of using NIR spectra that are collected by small hand-held scanner, on food

ISSN PRINT 2319 1775 Online 2320 7876
Research paper Volume 11, Iss 9, 2022

nutrition prediction.Diet monitoring is one of the most important aspects in preventative health care that aims to reduce various health risks. Manual recording has been a prevalence among all approaches yet it is tedious and often end up with a low adherence rate. Several existing techniques that have been developed to monitor food intake suffer too with accuracy, efficiency, and user acceptance rate.

M. Jihua, L. Zhongyuan, W. Bingfang and X. Jin, et.al [13] The factual base of precision agriculture (PA) - the spatial and temporal variability of soil and crop factors within or between different fields has been recognized for centuries. Field information on seeding suitability, soil & crop nutrition status and crop mature date is needed to optimize field management. How to acquire the spatially and temporally varied field parameters accurately, efficiently and at affordable cost has always been the focus of the researches in the field. Satellite remote sensing has held out much promise for within & between-field monitoring, along with the promising development regarding spatial, temporal and spectral resolution in the last decade. Scientists from all over the world have provided a great deal of fundamental information relating spectral reflectance and thermal emittance properties of soils and crops to their agronomic and biophysical characteristics. This knowledge has facilitated the development and use of various remote sensing methods to detect spatially and temporally varied environmental stresses which limit crop productivity. This can make significant contribution in optimizing crop management as sowing, irrigation, fertilization and harvest. However, gathering, accessing, and processing of remote sensing images from different satellites require high technical skills, not mention the time consumed in processing large amount of images. The lack of comprehensive software platforms to extract useful spatially and temporally varied information from satellite image hindered the wide application of satellite image to support PF. With this back ground, an integrated satellite-based field monitoring system was designed and developed with .Net and IDL (Interactive Data Language). The system consists of 4 primary functional models: 1) satellite image pre-processing model; 2) field seeding suitability evaluating model; 3) soil & crop nutrition status monitoring model and 4) crop mature date predicting model.

E. -Y. Lin, D. -L. Yang and M. -C. Hung, et.al [14] the system design of an intelligent consultation and recommendation framework to assist nutritionists in the environment of cloud computing. We employ the data mining technology of predicting and finding suitable patterns to help nutritionists develop personalized, comprehensive nutrition programs for customers. Decision tree analysis is used to find the matching pairs between customers¡¦ physiological states and their proper diet programs. This system can not only help nutritionists provide better services, but also assist customers to track physiological data, meals, and exercise information. The result demonstrates that our design can serve as a model of intelligent systems for both service providers and consumers. Information and communication technologies have been used to provide valuable services in our daily lives in the form of consultation and recommendation. However, the key factor of a successful service model is the integration of domain knowledge.

A. B. Ocay, J. M. Fernandez and T. D. Palaoag, et.al [15] design and develop an Android-based food recognition application that could be used as a health awareness tool for non-health conscious individual. The application lets the user take the photo of the food and show its nutritional contents. Implementing Mifflin-St Jeor method in determining daily calorie consumption, users shall be aware of their required calorie intake. Moreover, the researchers' have studied its effect on people's health awareness on food nutrition by the randomly

ISSN PRINT 2319 1775 Online 2320 7876
Research paper Volume 11, Iss 9, 2022

selected respondents. Finally, this paper presents an analysis of the impact of the food recognition app to change people's concept of food nutrition. One of the emergent concerns of human life is about health and wellness. Undeniably, health and nutrition are one of the valuable aspects of life. Thus, technological innovations to help enhance and even promote health awareness is essential. With the advent of mobile computing, it is much easier to be aware of health information because of its mobility and availability. Much mobile application is being developed to serve as a tool for health monitoring and nutritional guide. Mobile applications have the ability to support health needs like detecting heart rate, classifying food, and many more. Taking advantage of technology, utilization of it hereby addresses certain issue and problems of human life, especially in health.

III. METHODOLOGY

In this section framework of an automated, predictive infant's growth and nutrition monitoring system through IoT. Child information database: It includes the child growth and related contextual information including, height and head circumference, measurement date, and the result of growth analysis.

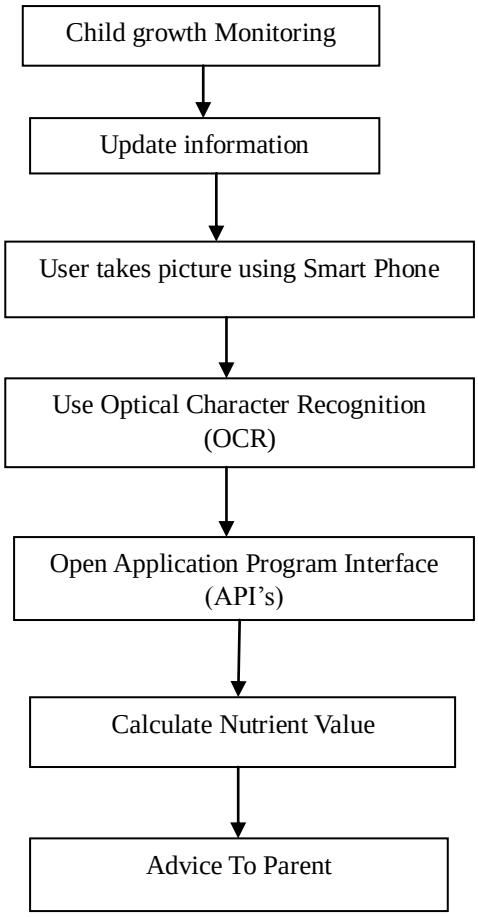

Fig.1: Framework Of An Automated, Predictive Infant's Growth And Nutrition Monitoring System Through IoT

Growth & development database: It stores the standard data collected by WHO. This data is used to draw growth charts and analyze growth data. Moreover, Development database includes the skills and abilities that children attain in each age range.

ISSN PRINT 2319 1775 Online 2320 7876
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Nutrition database includes three classes of information. One class is used to make diet recommendations. Another class is used to create the allowed food guidance. The last class includes recipes (including the name of foods and their recipes). Instruction database: It contains the health education information including public health, oral and dental care, as well as food instructions including recommendations for bad eating habits, the child's anorexia, the ways of enriching foods, and recommendations for obesity or impotence.

The proposed smart sensor system consists of piezoelectric sensors paired with a microcontroller. Piezoelectric sensors generate equivalent voltage signals for the applied weight or mechanical force. Piezo-sensors are generally used as force or vibration sensing as they dynamically give a corresponding voltage value equivalent to the applied force. By using the piezoelectric sensors in weight sensing application as this, they can help in sensing the variations in the total weight and consumed weight of the product, which can be used to calculate the nutrient values. This equivalent voltage value can be read with the help of the microcontroller which also saves the obtained value along with the time stamp.

The main reason behind using the microcontroller in this application is that it offers scheduling and easier integration into wireless modules, which helps in connecting the prototypes to the IoT. Gathering information regarding food is the most important task in any food monitoring system. All the related prior research was focused on achieving this through computer vision and mapping it to already existing information. The time and weight of the food product is obtained through the piezoelectric based sensor board.

In order to map the relevant nutrient values to these products, two approaches have been incorporated along with the sensor board. The nutrition information can either be captured as images through a smart phone and by using Optical Character Recognition (OCR) techniques, the appropriate information is stored in the database. OCR helps in identifying the printed characters in images. Another approach suggested is by linking open source Application Program Interfaces (APIs) through the barcode in to obtain the nutrient values. When the user opts to use the OCR method, the user initially needs to take a picture of the order nutrition facts label in that particular product. When the user opts to use the API approach, the barcode of the product is scanned using a smart phone. Along with the nutrient values obtained either through the OCR or API approach and the weight and time values obtained from the sensor board, the nutrient values for that meal are calculated.

The main concern in infants is the amount of food wasted after each meal. In spite of getting the right formula, and making the best efforts to prepare a balanced diet everyday, the food can only offer all the benefits if it is being consumed. In order to have an accurate measure of the wasted food, the weight of the wasted food is calculated. By taking the weight of the wasted food, corresponding nutrient value is calculated.

The purpose of each meal may vary from person to person. For example, some would like to have high fiber in their breakfast and a carbohydrate rich lunch, whereas some would like to have carbohydrates in the form of fruits and increase protein in their breakfast and lunch. Getting feedback from the user about the goals of a particular meal is necessary to provide suggestions for future meals and to determine if the user has maintained a balanced meal in that day.

ISSN PRINT 2319 1775 Online 2320 7876
Research paper Volume 11, Iss 9, 2022

IV. RESULT ANALYSIS

In this section result analysis of an automated, predictive infant's growth and nutrition monitoring system through IoT is observed.

Table.1: Performance Analysis

Parameters	uHPS	S2NI	IoT Sensors
Accuracy	91	86	99
Efficiency	89.7	90.9	98.4
Recall	82.9	94.7	95.8

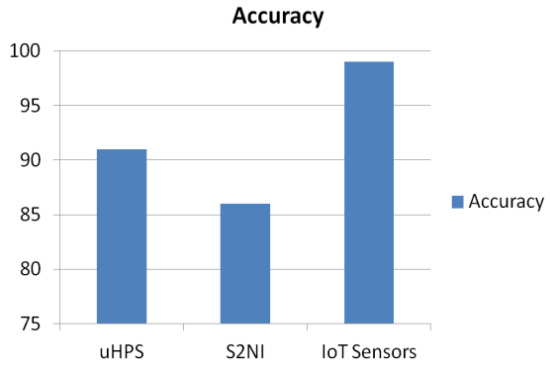

Fig.2: Accuracy Comparison Graph

In Fig.2 accuracy comparision graph is observed between uPHS, S2NI and IoT sensors.

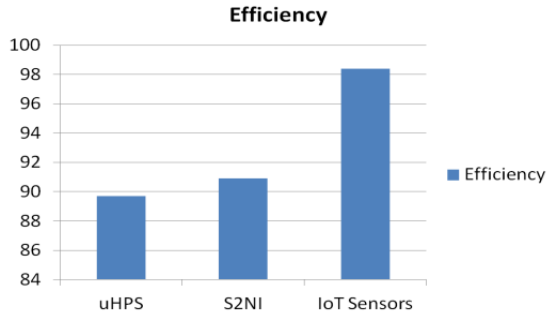

Fig.3: Efficiency Comparison Graph

Efficiency comparision graph is observed in Fig.3 between uPHS, S2NI and IoT sensors.

ISSN PRINT 2319 1775 Online 2320 7876
Research paper Volume 11, Iss 9, 2022

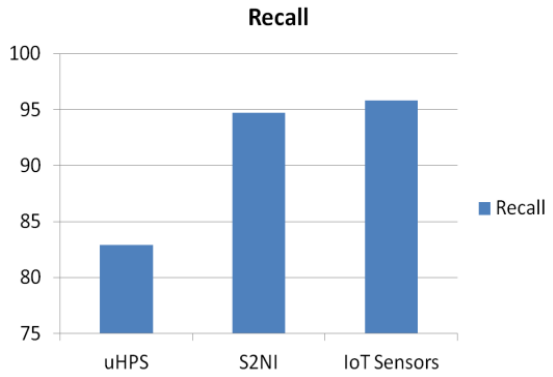

Fig.4: Recall Comparison Graph

In Fig.4 Recall Comparison Graph is observed between uPHS, S2NI and IoT sensors. An IoT sensor shows high recall.

V. CONCLUSION

In this framework of an automated, predictive infant's growth and nutrition monitoring system through IoT. Infant's growth and nutrition monitoring has been proposed to help parents improve the childcare process. This system consists of two mobile tiers and applications including the parental and the doctor's side. It has the growth and nutrition monitoring, health monitoring and doctor intervention functionalities. This helps in improving the overall efficiency, accuracy and recall of the system. The proposed system can help in analyzing the nutrition consumed on an everyday basis and provide suggestions for the user to address malnutrition. With a cost effective sensor system and seamless data logging method, the proposed system can be an essential consumer electronic device used in child care.

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