# Assessment of Couple Unmanned Aerial Vehicle-Portable Magnetic Resonance Imaging Sensor for Precision Agriculture of Crops

Balogun Wasiu A., Keshinro K.K, Momoh-Jimoh E. Salami, Adegoke A. S., Adesanya G. E., Obadare Bolatito J

**Abstract**— This paper proposes an improved benefits of integration of Unmanned Aerial vehicle (UAV) and Portable Magnetic Resonance Imaging (PMRI) system in relation to developing Precision Agricultural (PA) that is capable of carrying out a dynamic internal quality assessment of crop developmental stages during pre-harvest period. A comprehensive review was carried out on application of UAV technology to Precision Agriculture (PA) progress and evolving research work on developing a Portable MRI system. The disadvantages of using traditional way of obtaining Precision Agricultural (PA) were shown. Proposed Model Architecture of Coupled Unmanned Aerial vehicle (UAV) and Portable Magnetic Resonance Imaging (PMRI) System were developed and the advantages of the proposed system were displayed. It is predicted that the proposed method can be useful for Precision Agriculture (PA) which will reduce the cost implication of Pre-harvest processing of farm produce based on non-destructive technique.

**Index Terms**— Unmanned Aerial vehicle, Portable Magnetic Resonance Imaging, Precision Agricultural, Non-destructive, Pre-harvest, Crops, Imaging, Permanent magnet

## 1 Introduction

DURING agricultural processing, quality control ensure that food products meet certain quality and safety standards in a developed country [FAO]. Low profits in fruit farming are subjected by pre- and post-harvest factors. Pre-harvest features comprises stage of fruit development, tree health, climatic situations and fruit type and, there will be a high yield, if these pre-factors are properly taken care before post-harvest(Kassa Melese A, 2015 [1]).

Palms plantation inspection in a traditional way it's an unproductive technique which needs post processing and special skills in handling some of the tools. However, a lot of man hour are spent with extra overheads during surveillance in an unfavourable weather condition which result to not offering inclusive and correct data, since a lot of important factors are overlooked or not considered owing to bad terrain and dangerous animals within the plantation (Shamshiri R R et al, 2018 [2]).

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Inspection of fresh fruit bunches (FFB) for harvesting is a rigorous assignment which can be overlooked or applied physical counting that are usually not accurate or precise (Shamshiri R R et al, 2018 [2]).

This process of quality control includes determining the external and internal quality of the farm produce (Kassa Melese A, 2015 [1], Ebrahimnejad, H et al, 2018 [3]). However, there is a need to acquire necessary quality information especially internal quality of these farm produce during pre-harvest meaning before getting to consumer or end users. Under internal quality control the firm (quality control inspector) earns two categories of costs (i) the direct cost when it spends in learning about quality through inspection, testing and audits (ii) the opportunity cost when it keeps sub-standard farm yields from being released into the market (Kassa Melese A, 2015 [1], Ebrahimnejad, H et al, 2018 [3]).

Meanwhile, one major way to perform this assessment is to do on the spot farm inspection during the developmental stages of the produce at the farm (pre-harvest inspection) and the known method is mostly destructive techniques, labour intensive and couple with high cost (Wasiu A. Balogun et al, 2019[4], Tadhg Brosnan, 2004 [5]).

Different research work has been done in agricultural precision (PA) but the one that is based on internal assessment of these crops during developmental stages without being destructive applying a combined technology of UAV and portable MRI is still inadequate or deficient.

## 2 Magnetic Resonance Imaging

Numerous non-destructive procedures, such as ultrasonic, vibrated excitation, impedance, laser spectroscopy, reflectance, X-ray Imaging, transmittance, absorbance spectroscopy and near infrared imaging (NIR) have been developed to evaluate the internal quality of farm produce. In the meantime, their industrial submissions to both internal and external quality sorting are inadequate owing to hitches with precision and approach. (Kerr et al, 1997 [6], (Ruiz-Altisent et

al, 2010 [7], Fraunhofer-Gesellschaft, 2008 [8]).

A non-destructive method known as Magnetic Resonance Imaging (MRI) offers internal status structure data in a form of image and it offers deep understanding of atomic structure of substance. (Yacob et al, 2005 [9], McCarthy, 2016 [10]; Hills, 1998 [11]). However, MRI permits a non-destructive assessment of the internal quality possessions of fresh agricultural produce and applying this at a smaller budget would convey a required more worth to the agricultural produce (Kerr et al, 1997 [6], Ruiz-Altisent et al, 2010 [7], Balogun W.A et al 2013[12]). Unfortunately, there is an inadequacy in the over-all usage of MRI technology owing to the huge size, cost of production and complex technicality involved (Mika Koizumi et al, 2008 [13].

Balogun et al, 2019 [4], Boesch, 2020 [14]) stated Nobel Prizes winner on MRI and their various contribution which can be traced from Otto Stern (1943) for his starring role to the advancement of the molecular ray method and finding of the magnetic moment of the proton, Isidor I. Rabi (1944) in physics for his resonance technique research work in recording the magnetic properties of atomic nuclei, Felix Bloch and Edward M. Purcell (1952) for the development of new techniques in the field of nuclear magnetic precision measurements and discoveries in association there with Nicolaas Bloembergen (1981) in physics for his role to the contributions of laser spectroscopy -Theory of NMR relaxation.

Further research that led to Nobel Prizes was performed by Richard Ernst (1991) in chemistry for his development to the contributions in the research methodology of high resolution nuclear magnetic resonance (NMR) spectroscopy-Pulsed techniques and Fourier transform methods, Kurt Wütrich (2002) in chemistry for his contributions on nuclear magnetic resonance spectroscopy for determining the three dimensional structure of biological macromolecules in solution, Paul C. Lauterbur and Sir Peter Mansfield (2003) in physiology or medicine for their finding concerning magnetic resonance imaging (Fraunhofer-Gesellschaft, 2008 [8], Balogun et al, 2019 [4] and Boesch, 2020 [14]).

## 3 MRI-PORTABLE TECHNIQUE

The word MRI is commonly referring to an equipment which are costly, huge and have application or usages mainly in the medical fields. However, inventors recently started researching into a modern portable MRI sensor that can operate in the icy area scanning through the snow interiors. (Fraunhofer-Gesellschaft, 2008 [8], Bashyam A et al, 2018 [15]).

The huge size of common MRI scanner is primarily due to bulky magnets which produces a realistic magnetic field that generate an image of object (Fraunhofer-Gesellschaft, 2008 [8]). Fourier transformation method using reconstruction analysis creates an image from MRI signals. Therefore, to generate a high signal-to-noise ratio a larger magnetic field strength ($B_o$) must be available which resulted to bigger size and high cost commeasurable to huge and hefty configuration of one or the other permanent magnet or supercnducting magnet (Fraunhofer-Gesellschaft, 2008 [8]). (Bashyam A et al, 2018 [15], Clarissa Z. C et al, 2014 [16])

Magnet is the largest part in an MRI machine structure, however, with increase in researches there is a developmental stages of new methods towards making the size of MRI system decrease. (Fraunhofer-Gesellschaft, 2008 [8], Ali T.S et al, 2019 [17])

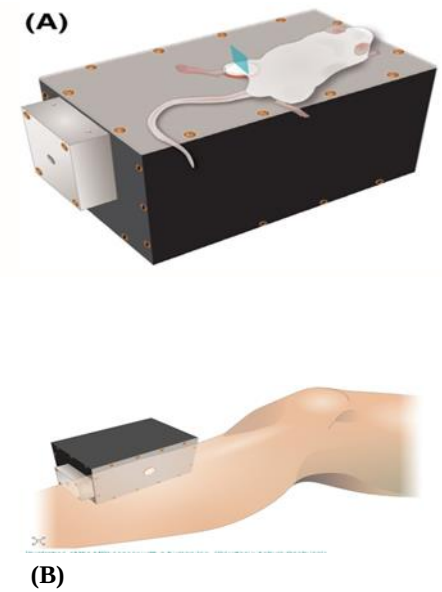
Therefore, if a permanent magnet/magnet array is applied to make available such a magnetic field (B0-field), the weight, spatial encoding magnetic (SEM), and its size can be decreased and in the meantime the imaging volume can be enlarged, contribution prospects to develop a really not expensive portable MRI system. For these methodologies, static field patterns devoid of spatial linearity are applied to convert MRI signals into imaging. (Fraunhofer-Gesellschaft,2008 [8], Bashyam A et al, 2018 [15] Petrov OV et al, 2019 [18]).

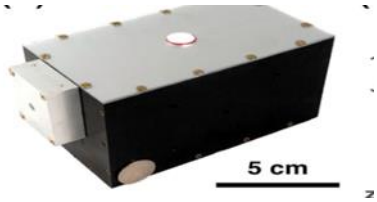
Portable MRI sensors in term of user operation is easier and there is no need of expert worker since image acquirement techniques is absent. It allows total automation of the whole process in the real time within a fraction of minutes and possesses an extensive medical usage. (Clarissa Z. C et al, 2014 [16], Ali T.S et al, 2019 [17], He Z et al, 2017 [19], Tourell M C et al, 2018 [20], Bashyam, A, 2019 [21]).

Bashyam, A, 2019 [21] performed an experiments of applying a magnet array or permanent magnet to provide static magnetic fields as spatial encoding magnetic by means of non-linear gradient for image reconstruction in a portable setup. As a matter of fact, permanent magnets do not require power consumption nor necessitate a cooling as compared to superconducting magnets and electromagnets. (Bashyam, A, 2019 [21], Shao Ying H, 2018 [23]) shows that there is a prospect to develop portable low-cost MRI system due to the uncomplicatedness and reduction in price of permanent magnets

Researcher from Fraunhofer Institute team up with Magritek firm, were able to develop a portable MRI sensor that can operate mainly on battery with a set-up of superfluous durable permanent magnets that does not required cooling system as compared to the conventional MRI machine that uses bulky superconducting magnetic body (Fraunhofer-Gesellschaft, 2008 [8] Bashyam, A, 2019 [21]).

This pocket size MRI are used to illustrate the internal quality and structure of polymer, determine the moisture content of substance and internal features of timbers (Fraunhofer-Gesellschaft, 2008 [8]).






**(C)**

Fig. 1 (A) Portable MRI sensor with a Mouse (B). Portable MRI sensor Placed on human leg (Physics world 28 0ct 2019 Tami freeman, Ashvin Bashyam (C) Picture of fully assembled Portable MRI sensor (Bashyam, A. et al, 2019 [21])

Bashyam, A et al, 2019 [21] developed a pocket size MRI sensor with a mass of 4Kg and size approximately 1000 $cm^3$ in figure (1) compared to conventional types which is deficiency in transportability due to its huge size, extremely expensive and prolonged duration of operation. It is a single-sided system that carry out its operation by placing the outer part of the magnetic material of the system beside the specimen.

The portable Magnetic Resonance device constructed gives extraordinary accurate results achieved from the arrangement of permanent magnet that produces a magnetic field of 0.28T, implement T2 relaxometry on mouse foot with the result after dehydration specifying decline in decay period of 45.4 from 67.1ms as shown in figure (1) and (2) (Bashyam, A. et al, 2019 [21]).

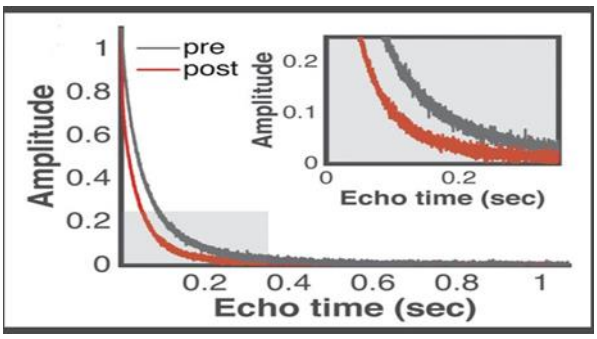



Fig. 2. T2 Relaxometry decay (Bashyam, A. et al, 2019 [21])

The result from figure 2 above show after dehydration specifying extreme reduction in decay period of 40 from 200ms which indicates excellent performance of the portable MRI system (Bashyam, A. et al, 2019 [21]).

## 4 UNMANNED AERIAL VEHICLE (UAV) TECHNOLOGY

Unmanned aerial vehicle (UAV) technologies are known as an autonomous aircraft that is fitted with control systems, telecommunication gadget, sensors and has ability to accomplish self-driving flight competence devoid of human interference (Junho Yeom et al, 2018 [24] Qijun Gu. et al, 2018 [25]) It is an airplane devoid of human pilot (Junho Yeom et al, 2018 [24], Wikipedia , 2019 [26]).

The origin of UAV development dated back to 1849 during war helping balloon carrier. Unmanned aerial vehicle (UAV) has different varieties which are categorized into five, based on their task and either autonomous or remote guided. They are namely unmanned spacecraft's, unmanned ground vehicles, unmanned aerial vehicles, unmanned underwater vehicles, and unmanned surface vehicles (operating on the surface of water) (Wikipedia, 2019 [26], Hazim Shakhatreh et al, 2019[27].

Any systems that is believed to be autonomous is required to operate by deciding which best path to execute an action devoid of people involvement or intervention (Hazim Shakhatreh et al, 2019 [27], Y. B. Sebbane, 2015 [28]).

TABLE 1
CATEGORIES OF NAMES FOR UNPILOTED AERIAL SYSTEM AND THEIR ACRONYMS

| S/N | Names of Unpiloted Aerial Systems | Acronyms |
|---|---|---|
| 1 | Unmanned Aerial Vehicle | UAV |
| 2 | Remotely Piloted Vehicle | RPV |
| 3 | Micro Aerial Vehicle | MAV |
| 4 | Uninhabited Combat Aircraft Vehicles/System | UCAV /S |
| 5 | Remotely Piloted Aircraft | RPA |
| 6 | Organic Aerial Vehicle | FVO |
| 7 | Uninhabited Combat Aerial Vehicle | UCAV |
| 8 | Micro Aerial Vehicle) | MAV |
| 9 | Drone | Not available |
| 10 | Aerial Robotics | Not available |
| 11 | Passenger Drone | Not available |

Table 1 indicates different names for unpiloted aerial system and their acronyms A. Korchenko et. Al, 2013 [29], Wikipedia, 2019 [30], Wikipedia, 2019 [31], Prisacariu v, 2017 [32])

Unmanned aerial vehicle (UAV) technologies have developed quickly over the past few years, with unlimited prospective for improvement in agriculture applications (AP). UAV remote sensing expertise allow accurate data collation at the field scale with spatial and time-based resolutions that were before unavailable via old method of remote sensing (Junho Yeom et. Al, 2018 [24]).

Comparing the remote sensing information from traditional methods for satellite and aerial images are less precise than the UAV information. Therefore, UAV images have abundant potential for many agricultural usages due to its right timing, suitability and precise information. (Junho Yeom et al, 2018 [24]).

The United State of America farmer reported that almost $33 billion income are unrecoverable from the impact of diseases invasion of various farm. This loss may be regained using acquire aerial images obtain from UAV technology to supervise and detect initial growth of soil-borne fungus in the farm (Hazim S et al, 2019 [27], Calderon R. et al, 2013 [35], Pimentel D. et. Al, 2005[36]).

In Thailand and Germany aerial photographs of crop obtained from UAV were used to predict or forecast harvest margin and rate of

growth (Hazim S. et al, 2019 [27], Geipel J. et al, 2014 [37] Hazim S. et al, 2019 [27]) study acquired 83.5% classification accuracy from aerial images of developmental stages of barley applying UAV technology

A group of UAVs which carried out functions as a distributed processing system were study (Chmaj G. et al, 2015 [34] Hazim S. et al, 2019 [27]) and were classify as in the Table 2.

TABLE 2
CATEGORIES OF OPERATIONS OF UAV

| S/N | Classification of Swarms UAV | Classification of Unmanned Vehicles |
|---|---|---|
| 1 | Object Detection | Unmanned Spacecraft's |
| 2 | Environmental Monitoring | Unmanned Ground Vehicles |
| 3 | Coordination | Unmanned Underwater Vehicles |
| 4 | General Purpose Distributed Processing Applications | Unmanned Surface Vehicles (Operating on the Surface of Water) |
| 5 | Collision Avoidance | Unmanned Aerial Vehicles |
| 6 | Tracking | Not Available |
| 7 | Navigation | Not Available |
| 8 | Surveillance | Not Available |
| 9 | Path Planning | Not Available |
| 10 | Data Collection | Not Available |

Zeng Y. et al, 2016 [38] shows monitoring of atmospheric pollution for surface vertical profiling and high-spatial-resolution in UAV technology is moving towards greater suitability as a smart research tools compared to earlier development of applying aircraft, satellite communication and balloon flight which remains costly to manage and un-navigable.

Watts, A.C et al, 2012 [39] and Qijun Gu et al, 2018 [40] indicate current innovations of capabilities of UAV to navigate in the air vertically and horizontally and at the same time still maintain stability during bad weather condition at a lesser budget for the monitoring project. (Everaerts, J, 2018 [41], Lei Feng et al, 2019 [42]) specify the benefits of extensive application of portable UAV in agriculture due to better efficiency, ecologically friendly and inexpensive. UAV telemetry supervised live, the various stages of crop development and provide real time solution (Hazim S. et al, 2019 [27], Lei Feng et al, 2019 [42]).

A research work reports shows different types of intelligent farming systems using UAV that carried out monitoring of pest control, disease discovery and stages of development of oil palm plantation making collation of data instantaneously available for fast precision agriculture (PA) decisions (Shamshiri R R et al, 2018 [2]).

Shamshiri R R et al, 2018 [2] study precision agriculture (PA) using traditional method of satellite images and remotely piloted aircraft (RPA) compared to UAV system and agribot (autonomous robot uses in farming) which are fast and accurate in terms of providing instant data of the plantation to the farmer. These data obtained are readily available for further assessment and forecasting crops income through computerization.

The data precision deficient in information obtained from satellite platforms, manned airplane and earth-based surveillance are readily available from UAV information. UAV have modernised intelligent agri-business with low cost implementation tailored for diverse agricultural functionality shorn of professionalism (Shamshiri R R et al, 2018 [2] Kalantar B et al, 2017 [43]).

Kurkute S. R. et al, 2018 [44] present QGIS software for examining inaccessible images and provide information on application of insecticide using camera with UAV on some section of farm plantation that is difficult to reach by farm worker.

(3A)

(3B)

Fig. 3A and 3B. Proposed UAV Hexcopter and Portable MRI system (Hexcopter that can carry heavy pay load)

Swati D Kale et al, 2018 [45] shows the algorithm to regulate variation in path to be taken by UAV relative to adverse change in weather condition during navigation of the farm. Another subject of concern is the law guiding UAVs flying rules however, it widely known that drone use farming operations usually work at low-flying level with small size over a secluded region (Swati D Kale et al, 2018 [45]).

Hazim Shakhatreh et al, 2019 [27] analysed the data of monetary value of Unmanned aerial vehicle and shows that application in agriculture nearly dominate the market value after infrastructure application. (FAO, 2018 [46]) Indicates that there is a positive rule of law on the application of portable UAVs for farming which enable gathering information from different sources to make meaningfully decision.

By 2022 the world market demand for UAV is expected to be in the range of three to four (3-4) billion US dollars (Radiant Insights,

2020 [33], Shamshiri R R et al, 2018 [2]) as shown in figure 4.

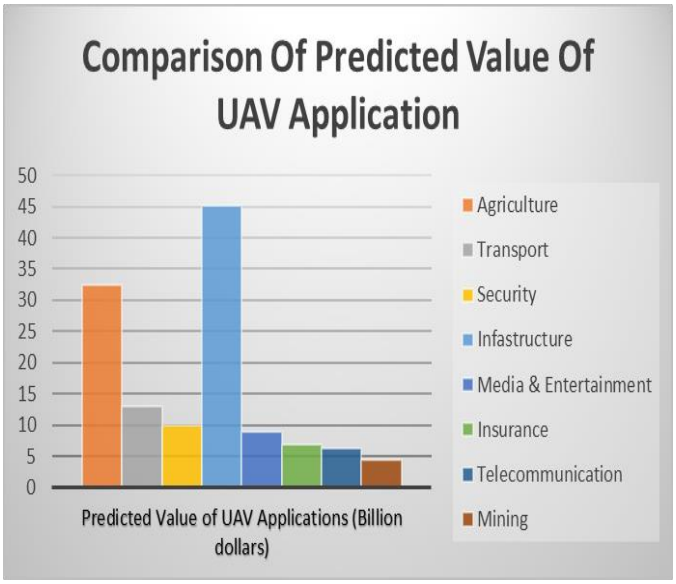



Fig. 4. Comparison of Predicted Value of UAV Application in Billion dollars (Hazim Shakhatreh et al, 2019 [27])

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## 5 Potential Innovation Of UAV and Portable MRI Integration Technology

At the moment, there is need to develop PA that will perform a vital part assessment of internal quality and save the cost in relations to workmanship, diseases monitoring mostly internal defect, chemical usages and water assessment and general supervision of developmental stages of crop in the farm plantation.

Our research work offers challenges and a modernize effect on the developing of a proposed novel techniques to evaluate the ability of combining the technology of portable MRI and UAV to obtain an images that can access on-line real time internal quality of crops during their developmental stages of pre-harvest.

Applying a real-time images of crops internal developmental quality data would propose an innovative advice setup to help farmer and researchers in making an important precise decision.

UAV drones can easily be modified to implement some of tedious work which ordinarily are difficult for human to achieve and at the same time in term of deployment, they are cheap, fast, non-dangerous and highly excited in collation of data from the cultivated area.

The technicality behind propose model applied in cultivated area involves the combination of UAV, control system, developing algorithms, vision sensing and portable miniaturized MRI sensor. Figure 5 show the block diagram of our proposed integration model architecture of Coupled UAV and Portable MRI Sensor system.



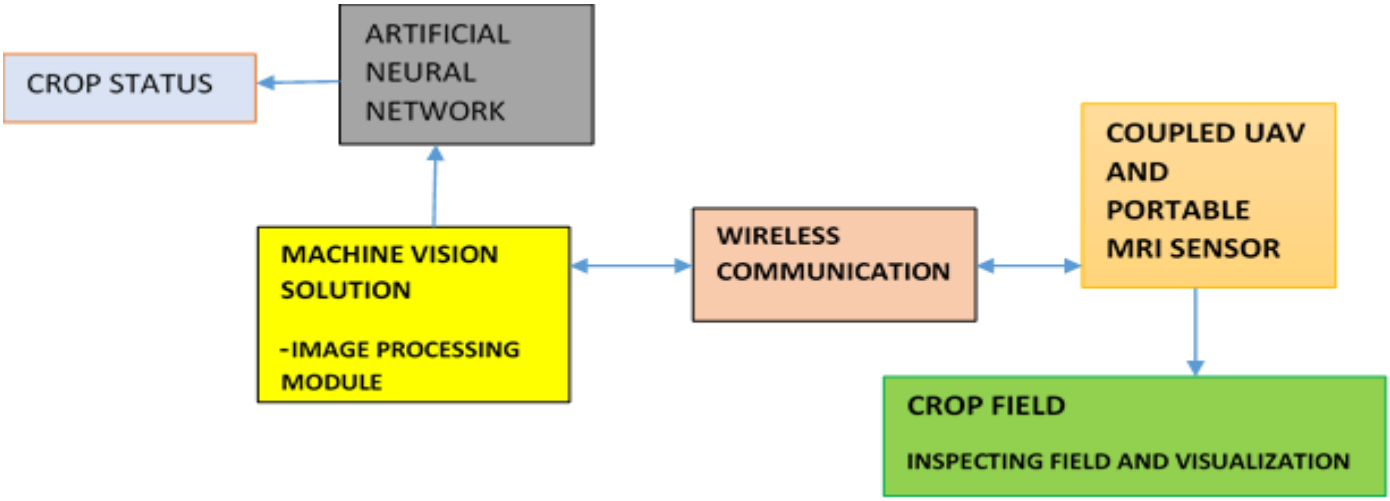


Fig. 5. Propose Model Architecture of Coupled UAV and Portable MRI System

Kurkute1 S. R. et. al, 2018 [44] put forward a design built on UAVs couple with auto control system to sprinkle chemicals on farm which can be adopt for the proposed couple UAV and portable MRI design.

## 6 Conclusion

So far, a lot of research and exploration have been carried out on the agricultural application of UAV. However, most of them have focused on the field of determining the external quality and there are no studies known to have explored the technology of combining

UAV and Portable MRI system.

Various benefits of this integration of UAV and portable MRI system will be achieved but majorly the cost of pre/post-harvesting processing and cost of applying chemical on the crop field will be drastically reduced since only crops with identify internal defect will be concentrated on for treatment while the healthy one will be free from chemical application. The man hour will improve, cost of farming will reduce, and high yield will be achieved from the crop produce by the farmer.

In this paper, we review several UAV applications and identify their structures. We also converse the research developments for UAV with the progress in portable MRI system technology and applications. The reason to undertake this study is the lack of a research focusing on these issues. A thorough explanation and discussion of the propose model will be presented in an upcoming conference.

## REFERENCES

[1] Kassa Melese Ashebre (2015), Pre-Harvest and Post-Harvest Factors Affecting Citrus Fruit and Post-Harvest Treatments Journal of Biology, Agriculture and Healthcare. Retrieved from: www.iiste.org, ISSN 2224-3208 ISSN 2225-093X (Online) Vol.5, No.23, 2015

[2] Redmond Ramin Shamshiri et. Al (2018), "Fundamental Research on Unmanned Aerial Vehicles to Support Precision Agriculture in Oil PalmPlantations". : https://www.intechopen.com/books/agricultural-robots-fundamentals-and-applications/fundamental-research-on-unmanned-aerial-vehicles-to-support-precision-agriculture-in-oil-palm-planta

[3] Ebrahimnejad, H.; Ebrahimnejad, H.; Salajegheh, A.; Barghi, H (2018), Use of Magnetic Resonance Imaging in Food Quality Control: A Review. Journal of biomedical physics & engineering, 8(1), 127-132

[4] Wasiu A. Balogun, Momoh-Jimoh E. Salami, Abiodun M. Aibinu, Adesanya Gbenga, Keshinro K..K (2019) Magnetic Resonance Imaging (MRI) Theory and Imaging Techniques: A Technical Mini-Review. Retrieved from: http://www.ijser.org ISSN 2229-5518 IJSER © 2019

[5] Tadhg Brosnan, Da-Wen Sun (2004), Improving quality inspection of food products by computer vision: A Review. Journal of Food Engineering 61 (1). 3-16

[6] W.L. Kerr, C. J. Clark, M. J. McCarthy, and J. S. De Ropp.(1997) "Freezing effects in fruit tissue of kiwifruit observed by magnetic resonance imaging." Retrieved from: Scientia horticulturae, vol. 69, no. 3, pp. 169-179

[7] M. Ruiz-Altisent, L. Ruiz-Garcia, G. P. Moreda, R. Lu, N. Hernandez-Sanchez, E. C. Correa, B. Diezma, B. Nicolaï, and J. García-Ramos (2010). "Sensors for product characterization and quality of specialty crops—A review." Retrieved from: Computers and Electronic in Agriculture, vol. 74, no. 2 pp. 176-194

[8] Fraunhofer-Gesellschaft. (2008) "Pocket-sized Magnetic Resonance Imaging." Retrieved from: www.sciencedaily.com /releases/2008/07/080708101131.htm>. ScienceDaily. ScienceDaily, 10 July.

[9] Yacob Y, H. Ahmad, P. Saad, R. Aliana, A. Raof, and S. Ismail. (2005) "A comparison between X-ray and MRI in postharvest non-destructive detection method." Proceedings of the International Conference on Information Technology and Multimedia at UNITEN (ICIMU'05), Malaysia.

[10] M.J. McCarthy1, L. Zhang1, K.L. McCarthy and T Coulthard (2016) 'Status and future of magnetic resonance imaging sensors for in-line assessment and sorting of fruit'. Department of Food Science and Technology, University Acta Hortic. 1119. ISHS. DOI 10.17660/ActaHortic.2016.1119.16 XXIX IHC – Proc. Int. Symposia on Abscission Processes in Horticulture and Non-Destructive Assessment of Fruit Attributes Eds.: J.N. Wünsche et al.

[11] Hills, B. (1998). *Magnetic resonance imaging in food science* (1st ed., pp. 161-243). Norwich, NY: John Wiley & Sons.

[12] Balogun W.A, Momoh-Jimoh E. Salami, Michael J. McCarthy, Yasir M. Mustafah, Abiodun M. A.,(2013). Intelligent Technique for Grading Tropical Fruit using Magnetic Resonance Imaging. International Journal of Scientific & Engineering Research, Volume 4, Issue 7, July 216 ISSN 2229-5518 IJSER © 2013 http://www.ijser.org.

[13] Mika Koizumi, Shigehiro Naito, Nobuaki Ishida, Tomoyuki Haishi and Hiromi Kano (2008) A Dedicated MRI for Food Science and Agriculture Food Sci. Technol. Res., 14 (1), 74–82

[14] Boesch, C. (2020). Nobel prizes for nuclear magnetic resonance: 2003 and Historical perspectives. Retrieved 21 Jan. 2020 https://onlinelibrary.wiley.com/doi/full/10.1002/jmri.20120

[15] Bashyam A, Li M, Cima MJ (2018). Design and experimental validation of Unilateral Linear Halbach magnet arrays for single-sided magnetic resonance. Retrieved from: J Magn Reson. 2018;292:36–43

[16] Jason P. Stockmann, Brandon D. Armstrong, Mathieu Sarracanie, Michael H. Lev, Matthew S. Rosen, and Lawrence L. Wald (2014). Two-Dimensional Imaging in a Lightweight Portable MRI Scanner without Gradient Coils Clarissa Zimmerman Cooley. Magnetic Resonance in Medicine

[17] Ali TS, Tourell MC, Hugo HJ, et. Al (2019). Transverse relaxation-based assessment of mammographic density and breast tissue composition by single-sided portable NMR. Magn Reson Med. 2019; 82:1199–1213.

[18] Petrov OV, Stapf S (2019). Multicomponent analysis of T1 relaxation in bovine articular cartilage at low magnetic fields. Magn Reson Med. 2019;81:2858–2868

[19] He Z, He W, Wu J, Xu Z (2017). The novel design of a single-sided MRI probe for assessing burn depth. Sensors. 2017; 17:526.

[20] Tourell MC, Ali TS, Hugo HJ, et al (2018). T1-based sensing of mammographic density using single-sided portable NMR. Magn Reson Med. 2018; 80:1243–1251.

[21] Bashyam, A., Frangieh, C. J., Li, M., & Cima, M. J. (2019). Dehydration assessment via portable, single sided magnetic resonance sensor. Magnetic Resonance in Medicine. doi:10.1002/mrm.28004

[22] Radunsky D, Blumenfeld-Katzir T, Volovyk O, et al (2019). Analysis of magnetization transfer (MT) influence on quantitative mapping of T2 relaxation time. Magn Reson Med. 2019;82:145–158.

[23] Shaoying Huang, Zhi Hua REN, Sergei Obruchkov, Jia Gong1, Robin Dykstra, Wenwei YU (2018). Portable Low-cost MRI System based on Permanent Magnets/Magnet Arrays.

*Investigative Magnetic Resonance Imaging*(2019), 23 (3):179

http://dx.doi.org/10.13104/imri.2019.23.3.179

[24] Junho Yeom, Jinha Jung, Anjin Chang, Murilo Maeda and Juan Landivar (2018). Automated Open Cotton Boll Detection for Yield Estimation Using Unmanned Aircraft Vehicle (UAV) Data. Remote Sens. 10,1895;doi:10.3390/rs10121895, www.mdpi.com/journal/remotesensing

[25] Qijun Gu, Drew R. Michanowicz and Chunrong Jia, (2018) Developing a Modular Unmanned Aerial Vehicle (UAV) Platform for Air Pol-

lution Profiling Sensors. 4363; doi: 10.3390/s18124363 www.mdpi.com/journal/sensors

[26] Wikipedia, "Unmanned_aerial_vehicle" (2019). [Accessed 12-10-2019]. https://en.wikipedia.org/wiki/Unmanned_aerial_vehicle

[27] Shakhatreh, H., Sawalmeh, A. H., Al-Fuqaha, A., Dou, Z., Almaita, E., Khalil, I., ... Guizani, M. (2019). Unmanned Aerial Vehicles (UAVs): A Survey on Civil Applications and Key Research Challenges. *IEEE Access*, *7*, 48572-48634. [8682048]. https://doi.org/10.1109/ACCESS.2019.2909530

[28] Y. B. Sebbane (2015). Smart Autonomous Aircraft: Flight Control and Planning for UAV. Retrieved from: CRC Press, November 18, 2015.

[29] A. Korchenko and O. Illyash (2013), The generalized classification of unmanned air vehicles. IEEE 2nd International Conference on Actual Problems of Unmanned Air Vehicles Developments Proceedings (APUAVD), 2013, pp. 28–34.

[30] Wikipedia, 'Drone Wikipedia' (2019) [Accessed 10-11-2019] [Online]. https://en.wikipedia.org/wiki/Drone

[31] Wikipedia, "Uncrewed-vehicle Wikipedia, the free encyclopedia," (2019), [Accessed 12-11-2019]. [Online]. https://en.wikipedia. org/wiki/Uncrewed-vehicle

[32] Prisacariu, v. (2017). The history and the evolution of uavs from the beginning till the 70s. Journal of Defense Resources ManagementVol.,8(Issue1(14),1-9. http://journal.dresmara.ro/issues/volume8_issue1/15_Vasile_PRISACARIU

[33] Global commercial drone market to exceed $2 Billion by 2022 - Radiant Insights. (2020). Retrieved 21 January 2020, https://www.radiantinsights.com/press-release/global-commercial-drone-market

[34] G. Chmaj and H. Selvaraj. (2015). Distributed processing applications for UAV/Drones: a survey. Progress in Systems Engineering. Springer, 2015, pp. 449–454

[35] Calderon R., J. A. Navas-Cort ´ es, C. Lucena, and P. J. Zarco-Tejada (2013). High-resolution airborne hyperspectral and thermal imagery for early detection of verticillium wilt of olive using fluorescence, temperature and narrow-band spectral indices. Remote Sensing of Environment, vol. 139, pp. 231–245

[36] D. Pimentel, R. Zuniga, and D. Morrison (2005). Update on the environmental and economic costs associated with alien-invasive species in the united states. Ecological economics, vol. 52, no. 3, pp. 273–288

[37] Geipel J, J. Link, and W. Claupein (2014). Combined spectral and spatial modelling of corn yield based on aerial images and crop surface models acquired with an unmanned aircraft system. Remote Sensing, vol. 6, no. 11, pp. 10 335–10 355

[38] Y. Zeng, R. Zhang, and T. J. Lim (2016). Wireless communications with unmanned aerial vehicles: opportunities and challenges. IEEE Communications Magazine, vol. 54, no. 5, pp. 36–42

[39] Watts A.C.; Ambrosia, V.G.; Hinkley, E.A. (2012). Unmanned Aircraft Systems in Remote Sensing and Scientific Research: Classification and Considerations of Use. Remote Sens. 2012, 4, 1671–1692

[40] Qijun Gu, Drew R. Michanowicz and Chunrong Jia (2018). Developing a Modular Unmanned Aerial Vehicle (UAV) Platform for Air Pollution Profiling Sensors. 4363; doi:10.3390/s18124363 www.mdpi.com/journal/sensors

[41] Everaerts, J. (2008). The use of unmanned aerial vehicles (UAVs) for remote sensing and mapping. Int. Arch. Photogramm. Remote Sens. Spat. Inf. Sci., 37, 1187–1192.

[42] Lei Feng 1,2, Weikang Wu 1, Junmin Wang 3, Chu Zhang 1 , Yiying Zhao 1, Susu Zhu 1 and Yong He (2019). Wind Field Distribution of Multi-rotor UAV and Its Influence on Spectral Information Acquisition of Rice Canopies. Remote Sens. 2019, 11,;doi:10.3390/rs11060602 www.mdpi.com/journal/remotesensing

[43] Kalantar B, Bin Mansor S, Sameen MI, Pradhan B, Shafri HZM (2017). Drone-based land-cover mapping using a fuzzy unordered rule induction algorithm integrated into object-based image analysis. Retrieved from: International Journal of Remote Sensing. May 2017 ;38(8–10):2535-2556

[44] S.R.Kurkute, B. D. Deore, Payal Kasar, Megha Bhamare, Mayuri Sahane (2018). Drones for Smart Agriculture: A Technical Report. Retrieved from: International Journal for Research in Applied Science & Engineering Technology (IJRASET) ISSN: 2321-9653; IC Value: 45.98; SJ Impact Factor: 6.887 Volume 6 Issue IV, April 2018- Available at www.ijraset.com

[45] Yallappa, D., Veerangouda, M., Maski, D., Palled, V., & Bheemanna, M. (2017). Development and evaluation of drone mounted sprayer for pesticide applications to crops. 2017 IEEE Global Humanitarian Technology Conference (GHTC), 1-7.

[46] FAO 2018 E-AGRICULTURE IN ACTION: DRONES FOR AGRICULTURE Published by Food and Agriculture Organization of the United Nations and International Telecommunication Union Bangkok. ] Edited by Gerard Sylvester (2018).