Precision Agriculture using Cloud Computing: A Review

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Abstract - Precision agriculture has emerged as a promising approach to optimize crop yields and reduce waste. Precision agriculture has gained significant attention in recent years due to its capability to optimize agricultural practices and increase productivity while reducing costs and environmental impact. With the advent of cloud computing technologies, precision agriculture has become even more powerful, providing real-time data on crop health, soil moisture, temperature, humidity, and other factors that affect overall crop growth and yield. This paper provides a comprehensive review of precision agriculture using cloud computing, highlighting its benefits, challenges, and future prospects. We examine the key components of a cloud-based precision agriculture system, including data collection, storage, analysis, and visualization. We also discuss the potential applications of cloud-based precision agriculture in India, where agriculture is a critical sector for food security and economic growth. Finally, we identify the major challenges facing the implementation of cloud-based precision agriculture in India, such as limited internet connectivity, high cost of technology, and lack of skilled manpower, and suggest possible solutions to address these challenges. This review paper highlights the importance of precision agriculture using cloud computing in addressing the challenges facing agriculture in India and underscores the need for concerted efforts from various stakeholders to promote its adoption and implementation.

Index Terms - Cloud Computing, Internet of Things (IoT), Precision Agriculture.

I. INTRODUCTION

Agriculture is a critical sector that provides food, raw materials, and other essential products for human consumption. However, traditional agricultural practices have several limitations that impact productivity and sustainability. These limitations include:

a) Inefficient use of resources.
b) Imprecise application of inputs.
c) Lack of real-time monitoring and control.

Precision agriculture has emerged as a solution to address these challenges by utilizing technology to optimize agricultural practices. Cloud computing, with its scalable and flexible computing power, makes it possible to implement precision agriculture, offering cost-effective and efficient solutions to overcome the challenges faced by traditional agriculture methods.

Precision agriculture is required in India for several reasons:

A) Limited Resources:

India is one of the world's most populous countries and the demand for food is rapidly increasing. However, the available resources such as land and water are limited. Precision agriculture can help optimize the use of these resources thus making the agriculture process more efficient and sustainable.

B) Climate variability:

India is highly vulnerable to climate variability, with frequent droughts and floods. Delayed monsoon also heavily affects the production of crops. Precision agriculture can help farmers adapt to these changing conditions by analyzing the stream of data regarding the climate and soil moisture.

C) Small landholding size:

In India majority of farmers own small landholdings, making it difficult for them to adopt modern agricultural practices. Precision agriculture can help small farmers by providing them with access to advanced technology, such as drones and sensors, to help them make better crop decisions. Drones can also help in spraying pesticides on the crops in a more effective way hence reducing the usage of pesticides.

D) Increasing demand for food:

India's population is expected to reach 1.51 billion by 2030, putting pressure on the agricultural sector to increase food production. Precision agriculture can help increase yields while reducing costs, making agriculture more profitable and sustainable.

E) Environmental concerns:

The agricultural sector is a significant contributor to environmental degradation in India. Precision agriculture can help in minimizing the excess usage of pesticides, reduce soil erosion and help in reducing pollution.

Cloud Computing:

"Cloud computing is a model for enabling universal, on-demand, and convenient network access to a shared pool of configurable computing resources (e.g., networks, servers, storage, applications, and services) that can be rapidly provisioned and released with minimal management effort or service provider interaction"[1].

Cloud computing allows users to access and use various different computing resources over the internet, instead of using their local computer or server. Various computing resources used are servers, storage, databases, software applications, and more. Cloud computing enables users to access these resources on demand without the need for upfront investments in infrastructure or maintenance. Cloud computing is typically delivered through a service model, with different levels of service available depending on the needs of the user. These service models include:

1) Infrastructure as a Service (IaaS):

IaaS provides access to infrastructure resources such as virtual machines, servers, storage, and networking. The cloud provider manages virtualization, servers, and storage. The user handles all the remaining components including purchasing, installation, and configuration .IaaS enables data to be stored in different geographical locations.

2) Platform as a Service (PaaS):

PaaS is a development service offered to the user through the Internet [3]. PaaS provides access to the computing platform that allows users to develop, run and manage applications. In PaaS, the customer only has to manage the applications. PaaS allows you to avoid the expense and complexity of managing different licenses or development tools and other resources.

3) Software as a Service (SaaS):

SaaS provides access to software applications over the Internet, without the need for installation or maintenance on the user's local computer. It provides a complete software solution you can purchase on a pay-as-you-go basis from the cloud provider. In SaaS, all the required infrastructure, middleware, and app software are located in the cloud provider's data center. The service provider manages the hardware and software required to run the application whenever the user requests it. Some SaaS providers run on other cloud providers PaaS or IaaS offerings [3].

Examples of SaaS [4]:

a. Email and Office Productivity: Email applications, word editors and processors, spreadsheets applications, and presentations applications are typical examples in this category.

b. Billing: There are applications designed to monitor and manage customer billing. This is determined by users system usage and subscriptions to products and services.

c. Customer Relationship Management (CRM): CRM is a typical call-center application.

d. Financials: These are applications useful for tracking and reporting financial activities including the processing of expenditures, generating invoices, payroll, and managing taxes.

The different cloud service models are shown in Fig. 1.

Fig.1 Cloud Service Models

Cloud Architecture:

Cloud computing architecture refers to the design and structure of various components that make up a cloud computing system. The different components of cloud architecture are depicted in Fig. 2.

This architecture typically consists of four main components:

1. Front-end:
The front-end is the user-facing interface of the cloud computing system. It enables users to access cloud computing services and applications through a web browser or a mobile app. The front-end typically consists of a user interface, web servers, and application servers.

2. Back-end:
The back-end is the core of the cloud computing system. It consists of various components that handle data storage, processing, and management. The back-end typically consists of servers, storage devices, databases, and networking devices.

3. Cloud infrastructure:
The cloud infrastructure is the underlying foundation that supports the cloud computing system. It includes the physical resources, such as servers, storage devices, and networking devices, that are needed to host the cloud computing system. The cloud infrastructure can be located in one or more data centers, and it can be managed by the cloud provider or by the customer.

4. Cloud services:
Cloud services are the various software applications and services that are hosted on the cloud computing system. Cloud services can include infrastructure-as-a-service (IaaS), platform-as-a-service (PaaS), and software-as-a-service (SaaS) offerings. Cloud services can be provided by the cloud provider or by third-party vendors.

Cloud computing architecture can be classified into three main categories:

a. Public cloud architecture:

Public cloud architecture refers to a cloud computing system that is hosted and managed by a third-party cloud provider. Public cloud architecture is accessible over the internet, and it is available to anyone who wants to use it. Public cloud architecture is typically used by small and medium-sized businesses that want to reduce their IT costs and improve their scalability.

b. Private cloud architecture:

Private cloud architecture refers to a cloud computing system that is hosted and managed by an organization's internal IT department. Private cloud architecture is not accessible over the Internet, and it is available only to the organization's employees. Private cloud architecture is typically used by large organizations that want to have more control over their cloud computing resources and data.

c. Hybrid cloud architecture:

Hybrid cloud architecture refers to a cloud computing system that combines both public and private cloud architectures. Hybrid cloud architecture enables organizations to take advantage of the benefits of both public and private clouds. For example, a business can implement public cloud for non-sensitive data and applications, while using the private cloud for sensitive data and applications.

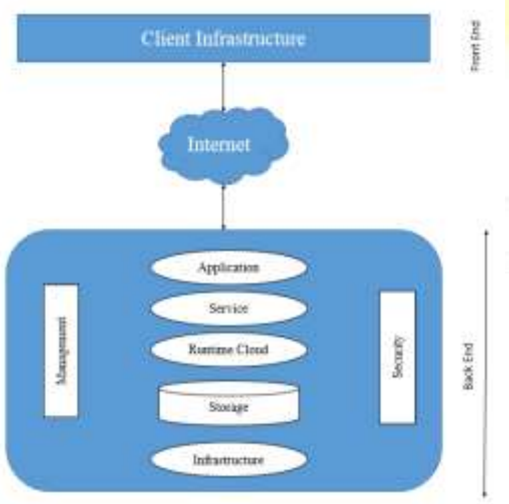

Fig.2 Cloud Architecture

Why Cloud Computing in Precision Agriculture:

Cloud computing has several benefits in precision agriculture, such as:

Scalability:
Scalability allows farmers to scale up or down their computing resources depending on the different resources that are needed. This allows them to be able to store and process large amounts of data without investing in expensive hardware. Cloud computing also enables farmers to use a pay-as-you-go model. This allows them to pay only for the resources they use.

Real-Time Data processing:
Cloud computing allows farmers to process data in real-time thus providing them with live data to make decisions that improve crop yields, reduce costs, and minimize environmental impact. It also enables farmers to detect and respond to crop diseases, pests, and other issues before they cause significant damage.

Data Sharing:
Cloud computing enables farmers to share data with other farmers, agronomists, and researchers to improve decision-making processes and collaboration. Data sharing can also help farmers identify best practices, benchmark against other farms, and identify areas for improvement.

Cost Savings:
Cloud computing enables farmers to reduce their IT costs, as they do not have to invest in expensive hardware or software licenses. Cloud computing also enables farmers to avoid the costs associated with maintaining and upgrading hardware and software.

Data security:
Cloud computing provides farmers with secure data storage, backup, and disaster recovery capabilities. Cloud computing also enables farmers to implement data security measures, such as access control, encryption, and data masking.

Challenges in Precision Agriculture:

Limited Internet Connectivity:
In many rural areas of India, internet is not available, or the internet connection is limited to lower speeds, making it difficult to implement and use precision agriculture technologies. Without reliable internet connectivity, farmers cannot access real-time data on weather conditions, soil moisture, temperature, and other factors that affect crop growth and yield.

Limited Awareness and Adoption:
There is a lack of awareness and knowledge about precision agriculture among farmers in India. Many farmers are not aware of precision agriculture and the immense benefits of precision agriculture therefore are reluctant to adopt new and advanced technologies and practices.

High Cost of Technology:
The cost of precision agriculture technologies, such as sensors, drones, and GPS systems, is often high, making it difficult for small and marginal farmers to afford them. The high cost of technology is a major barrier to the adoption of precision agriculture practices in India.

Lack of Standardization:
There is a lack of standardization in precision agriculture technologies, which can make it difficult to compare and integrate data from different sources. This can lead to inconsistencies in data and make it difficult to draw meaningful conclusions from the data.

Lack of Skilled Manpower:
There is a shortage of skilled manpower in India with the knowledge and expertise to implement precision agriculture practices. Without trained professionals, it is difficult to implement precision agriculture technologies effectively.

Proposed Solutions to Challenges in precision agriculture:

Improving Internet connectivity:
Limited internet connectivity is a major challenge facing precision agriculture in India. To address this challenge, the government can work to improve internet connectivity in rural areas by investing in infrastructure such as broadband networks and mobile towers. Private sector companies can also play a role in improving internet connectivity by developing innovative solutions such as low-cost internet devices and mobile apps. Some of the government initiatives are:

a) Digital India Initiative
b) BharatNet
c) PM Wani (Wifi Access Network Interface) scheme

Promoting the use of open-source technology:
The high cost of technology is a major challenge facing precision agriculture in India. To address this challenge, the government can promote the use of open-source technology, which is freely available and can be modified to suit the needs of farmers. This can help to reduce the cost of technology and increase its accessibility to farmers.

Developing skilled manpower:
A lack of skilled manpower is a major challenge facing precision agriculture in India. To address this challenge, the government can invest in training programs to develop skilled manpower in the areas of data analysis, machine learning, and other relevant skills. Private sector companies can also play a role in developing skilled manpower by partnering with educational institutions to provide training and internship opportunities.

Providing financial support:
Precision agriculture requires significant investments in technology and infrastructure. To encourage farmers to adopt precision agriculture practices, the government can provide financial support in the form of subsidies, loans, and grants. Private sector companies can also play a role in providing financial support by developing innovative financing models such as pay-as-you-go models.

Promoting farmer awareness:
A large population of farmers in India are unaware and uneducated about the benefits of precision agriculture. To address this challenge, the government and private sector companies can work together to promote farmer awareness through various channels such as farmer fairs, workshops, and mobile apps. Farmer awareness programs can help to increase the adoption of precision agriculture practices and improve agricultural productivity in India.

Key Components of Cloud-Based precision agriculture system:

1. Data Collection:
The first step in a cloud-based precision agriculture system is the collection of data from various sources. This can include satellite imagery, drones, weather sensors, soil sensors, and other sources. The data is collected in real-time and transmitted to the cloud for storage and analysis.

2. Data Storage:
Once the data is collected, it is stored in the cloud for processing and analysis. Cloud storage provides a secure and scalable way to store large amounts of data, without the need for local storage devices or servers. We can implement data storage using Azure Blob Storage which can be used to store unstructured data that is obtained from the continuous streaming of data from different sensors and IoT devices.

3. Data Analysis:
The data collected from various sources is analyzed using various techniques such as machine learning algorithms and predictive analytics. This helps in identifying patterns and trends in the data, which can be used to optimize crop management practices like irrigation, fertilization, and pest management. We can implement data analysis using Azure Stream Analytics which is designed to analyze and process large volumes of streaming data with sub-millisecond latencies.

4. Visualization:
The insights gained from data analysis are presented in a visual format, such as maps, graphs, and charts, to help farmers make more informed decisions. This can be done using cloud-based visualization tools that can be accessed from any device with an internet connection. Data visualization can be implemented using Azure PowerBi which visualizes data from Azure stream analytics.

II. Proposed Cloud-Based Agricultural Architecture

The proposed cloud-based architecture for precision agriculture depicted in Fig. 3 is composed of 5 major layers: Sensors and IoT devices, Cloud, Integrated agriculture Equipment, GUI, and End-User. In this section, we discuss these 5 layers in detail.
As seen from the figure given below, the system consists of several components:

1. Sensors and IoT devices:
These devices are installed in the field or on agricultural equipment to collect data on environmental factors such as temperature, humidity, soil moisture, and weather conditions.

2. Data transmission:
The collected data is transmitted to the cloud platform for storage and processing.

3. Cloud data storage and processing:
The data is stored in the cloud and processed using machine learning algorithms and data analytics tools to identify patterns and insights.

4. Precision agriculture equipment integration:
The system can be integrated with precision agriculture equipment such as GPS-guided tractors, drones, and irrigation systems, allowing farmers to automate and optimize their crop management practices based on the insights provided by the cloud platform.

5. Mobile app and dashboard:
The insights and data are presented to farmers through a mobile app or web dashboard, providing live information on crop health, weather patterns, and other environmental factors.

6. Collaborative tools:
The system includes collaborative tools to enable farmers to share data and insights with other farmers, agricultural professionals, and researchers.

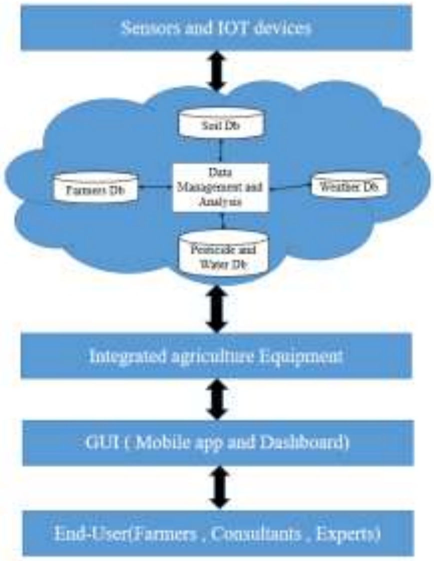

Fig. 3. Proposed cloud-based architecture for precision agriculture.

III. LITERATURE SURVEY

In this paper, we study the findings and analysis of the research carried out by different authors and we plot their key findings in a tabular format shown below.

Research Paper Title	Focus	Key Findings	Author	Source
[5]"Cloud-based application to process, analyze and visualize UAV-collected data for precision agriculture applications utilizing artificial intelligence (2020)"	"A cloud- and AI-based application to analyze and visualize UAV-collected data"	Cloud computing offers increased data storage and processing capabilities, but challenges remain in data privacy and security	Yiannis_Ampatzidis, Victor Partel, Lucas Costa	International Journal Computers and Electronics in Agriculture (Volume 174)

[6]"Cloud-based Decision Support and Automation for Precision Agriculture in Orchards (2016)"	"Cloud-based Decision Support and Automation systems that can acquire data from various sources, synthesize application-specific decisions, and control field devices from the Cloud."	Cloud-based DSAS is its ability to control field devices directly from the Cloud. Farmers often deploy a variety of devices for different applications where each device has its own interface.	Li Tan	IFAC-PapersOnLine Volume 56, Issue 1
[7]"iFarm: Development of Cloud-based System of Cultivation Management for Precision Agriculture (2013)"	"Cloud-based precision agriculture for providing farmers with real-time data."	Cloud-based data management to ensure efficient agricultural work through smartphone applications.	Yukikazu Murakami, Slamet Kristanto Tirto Utomo, Keita Hosono	2013 IEEE 2nd Global Conference on Consumer Electronics (GCCE)
[8]"Cloud-based prototype for the monitoring and predicting of data in precision agriculture based on internet of everything (2020)"	"Cloud-based system for monitoring and predicting data using IOE."	Cloud-based prototype for the monitoring and predicting of data in precision agriculture.	Suresh Kumar K Dr, Balakrishnan S	Journal of Ambient Intelligence and Humanized Computing 12(4):1-12
[9]"A software architecture based on FIWARE cloud for Precision Agriculture (2017)"	"Cloud-based software that uses an open-source cloud provider FIWARE."	An open source Cloud-based software that allows worldwide agronomical data to be stored in a common data warehouse.	J.A. López-Riquelme, N. Pavón-Pulido, H. Navarro-Hellín	Agriculture Water Management Volume 283
[10]"Precision Agriculture Using Cloud-Based Mobile Application for Sensing and Monitoring of Farms (2021)"	"Cloud-based precision agriculture using Raspberry Pi and mobile applications."	Implements different sensors that send data to the ThinkSpeak cloud application and notifies the farmers by sending an SMS	Ria Shrishti, Ashwani Kumar Dubey, Divya Upadhyay	Emerging Technologies in Data Mining and Information Security (pp 417–425)
[11]" Sensor-Cloud based Precision Agriculture Approach for Intelligent Water Management (2019)"	"A sensor-cloud-based precision agriculture for intelligent water management for effective productivity in agriculture."	Sensor-cloud technology allows for real-time data collection and is able to monitor the soil moisture content and automatically irrigate crops when necessary.	M.Jayalakshmi, V. Gomathi	International Journal of Plant Production volume 14, pages177–186 (2020)

[12]"A new mobile application of agricultural pest recognition using deep learning in cloud computing system (2021)"	"Development of a mobile application for the recognition of agricultural pests using deep learning in a cloud computing system."	Use of deep learning algorithms for pest recognition and classification. Integration of the mobile application with a cloud computing system for efficient processing and analysis of pest data.	Mohamed Esmail Karar, Fahad Alsunaydi, Sultan Albusaymi	Alexandria Engineering Journal (Volume 60 issue 5)
[13]" A Cloud-Based Framework for Agricultural Data Integration: A Top-Down-Bottom-Up Approach (2022)"	"Developing a cloud-based framework for integrating heterogeneous agricultural data from multiple sources"	The proposed framework utilizes a top-down-bottom-up approach to integrate data from different sources including satellite imagery, weather data, and on-farm sensor data. The framework is designed to be scalable, flexible and interoperable, allowing for the addition of new data sources as needed. This ensures that the framework can adapt to the changing needs of agricultural operations.	Anat Goldstein, Lior Fink, Gilad Ravid	IEEE Access Volume 10 Page(s): 88527 - 88537

IV. FUTURE DIRECTIONS AND OPPORTUNITIES FOR RESEARCH:

Precision agriculture using cloud computing is a rapidly evolving field with significant opportunities for research and development. Future research directions include developing advanced algorithms for data analysis and decision-making, integrating emerging technologies such as the Internet of Things (IoT) and Artificial Intelligence (AI), and exploring the potential for cloud robotics in precision agriculture. Some of the potential areas for future research are:

1. Integration of advanced technologies: Future research can explore the integration of advanced technologies such as artificial intelligence, machine learning, and big data analytics with cloud computing to further enhance precision agriculture practices.

2. Development of cloud-based precision irrigation systems: The development of cloud-based precision irrigation systems can help to optimize water usage and reduce wastage, which is especially important in water-scarce regions.

3. Integration of drones and cloud computing: The integration of drones with cloud computing can provide real-time data on crop health and growth, which can be used to optimize farming practices.

4. Cloud-based decision support systems: The development of cloud-based decision support systems can provide farmers with live and accurate readings of the weather conditions, soil moisture content, temperature, humidity, and other essential readings to help them make informed decisions.

5. Cost-benefit analysis: Future research can explore the cost-benefit analysis of implementing cloud-based precision agriculture systems and evaluate their economic viability and potential return on investment.

Overall, the integration of cloud computing in precision agriculture presents numerous opportunities for optimizing crop yield, reducing costs, and improving resource management.

V. CONCLUSIONS

Agriculture is one of the primary industries in the world, it aids in feeding billions of people around the world. With the implementation of advanced technologies and practices, traditional agriculture has transformed such that many of the operations in farming have been automated and have made farming less labor-intensive, while steadily improving the quality and yield of crops significantly. IoT-enabled sensors play a significant role in gathering live data from the crops which then sends the data through underlying communication technologies to the cloud for further processing and analysis. UAVs, actuators, and Drones along with AI are some of the major technological innovations in the field of agriculture. The combination of these advanced technologies allows us to gather live data and allows us to make instant and precise decisions without the need for human support, making farming more efficient and less labor-intensive.

In conclusion, precision agriculture using cloud computing is an emerging field that offers significant potential for optimizing agricultural practices and increasing productivity while reducing costs and environmental impact. In precision farming, to obtain high-quality products, the environmental parameters should be effectively monitored and controlled to provide optimal values. Cloud computing provides a platform for efficient data management, analysis, and decision-making, making it a promising solution for precision agriculture. The future of precision agriculture using cloud computing is exciting, with significant opportunities for research and development in this field.

VI. REFERENCES

[1] P. Mell and T. Grance, “The NIST Definition of Cloud Computing Recommendations of the National Institute of Standards and Technology,” Natl. Inst. Stand. Technol. Inf. Technol. Lab., vol. 145, p. 7, 2011

[2] Verma and S. Kaushal, “Cloud Computing Security Issues and Challenges: A Survey,” no. July, 2011, pp. 445–454.

[3] F. Hu et al., “A review on cloud computing: Design challenges in architecture and security,” Journal of Computing and Information Technology, vol. 19, no. 1. pp. 25–55, 2011.

[4] Cloud Taxonomy, https://cloudtaxonomy.opencrowd.com

[5] Yiannis Ampatzidis,Victor Partel,Lucas Costa, “Agroview: Cloud-based application to process, analyze and visualize UAV-collected data for precision agriculture applications utilizing artificial intelligence,”July 2020,volume 174.

[6] Li Tan ,"Cloud-based Decision Support and Automation for Precision Agriculture in Orchards,” IFAC-PapersOnLine,volume 49,Issue 16,2016,pp. 330-335.

[7] Yukikazu Murakami; Slamet Kristanto Tirto Utomo; Keita Hosono, “iFarm: Development of cloud-based system of cultivation management for precision agriculture,” 2013 IEEE 2nd Global Conference on Consumer Electronics (GCCE).

[8] Suresh Kumar K Dr,Balakrishnan S, “A cloud-based prototype for the monitoring and predicting of data in precision agriculture based on internet of everything, ” Journal of Ambient Intelligence and Humanized Computing, November 2020.

[9] J.A. López-Riquelme,N. Pavón-Pulido,H. Navarro-Hellín, F. Soto-Valles, R. Torres-Sánchez, “A software architecture based on FIWARE cloud for Precision Agriculture,” Agricultural Water Management Volume 183, March 2017,pp. 123-125

[10] Ria Shrishti,Ashwani Kumar Dubey,Divya Upadhyay, “Precision Agriculture Using Cloud-Based Mobile Application for Sensing and Monitoring of Farms” Emerging Technologies in Data Mining and Information Security, May 2021, pp. 417-425.

[11] M.Jayalakshmi, V. Gomathi. “Sensor-Cloud based Precision Agriculture Approach for Intelligent Water Management” International Journal of Plant Production, Volume 14, pp. 177-186 (2020).

[12] Mohamed Esmail Karar,Fahad Alsunaydi,Sultan Albusaymi, “A new mobile application of agricultural pests recognition using deep learning in cloud computing system” Alexandria Engineering Journal, Volume 60, Issue 5, October 2021, pp. 4423-4432.

[13] Anat Goldstein,Lior Fink, Gilad Ravid, “A Cloud-Based Framework for Agricultural Data Integration: A Top-Down-Bottom-Up Approach” IEEE Access, Volume 10 , August 2022, pp. 88527-88537.