Terms of Reference
ITU-T Focus Group on "Artificial Intelligence (AI) and Internet of Things (IoT) for Digital Agriculture" (FG-AI4A)

(Approved by ITU-T SG20 on 2021-10-21)

Rationale

The exceptional importance of the agricultural sector stems from a very simple reason: through providing sustenance, it is critical for our survival. This importance is reflected in its global economic value, which was 3.69 trillion US$ in 2020[1], and its average growth of ca. 2.7% over the last ten years[2]. Furthermore, farming provides jobs for 1.3 billion people, or 19% of the world's population.[3]

However, agriculture faces a multitude of challenges. For instance, production needs to accommodate a growing demand for food[4] and the impacts of hindered farming conditions in order to retain (or achieve) food security[5]. Traditional practices such as adding additional fertilizers or pesticides are coming to an end, as they are not sustainable.

To create practical solutions, AI needs to be explored in conjunction with IoT, connected services and autonomous systems. Ultimately, this will constitute an agricultural cyber physical system. IoT will provide the basic foundation to develop connected services, through employing (remotely connected) sensor/actuator networks, distributed computing devices, and cloud infrastructures. Autonomous systems include robotic systems that perform agricultural interventions such as measuring, sowing feeding or harvesting.

All this is made possible through the growth in the use of AI, of connective technologies such as the IoT, and of autonomous systems.

There are several applications of these technologies in agriculture[6], including:

- Greenhouse automation and industrialization
- Cattle monitoring and management
- Predictive analytics for smart farming
- Agricultural robotics
- Precision farming
- Crop management
- Agricultural knowledge and information systems
- Optimization of cultivable acreage
- End-to-end farm management systems

[1] "Agriculture, Forestry, and Fishing, Value Added (Current US$) | Data," accessed September 21, 2021, https://data.worldbank.org/indicator/NV.AGR.TOTL.CD.
[2] "Agriculture, Forestry, and Fishing, Value Added (Annual % Growth) | Data," accessed September 21, 2021, https://data.worldbank.org/indicator/NV.AGR.TOTL.KD.ZG.
[3] Deloitte. "Transforming Agriculture through Digital Technologies." Jan. 2020, www2.deloitte.com/content/dam/Deloitte/gr/Documents/consumer-business/gr_Transforming_Agriculture_through_Digital_Technologies_noexp.pdf.
[4] Michiel van Dijk et al., "A Meta-Analysis of Projected Global Food Demand and Population at Risk of Hunger for the Period 2010–2050," *Nature Food* 2, no. 7 (July 2021): 494–501, https://doi.org/10.1038/s43016-021-00322-9.
[5] Food and Agriculture Organization of the United Nations, *The Future of Food and Agriculture – Alternative Pathways to 2050.* (Rome, 2018), http://www.fao.org/3/I8429EN/i8429en.pdf.
[6] Warner, James. "How IoT Technology Is Shaping the Agriculture Industry?" CustomerThink, 27 Dec. 2020, customerthink.com/how-iot-technology-is-shaping-the-agriculture-industry/.

The shift from traditional agriculture to digital agriculture using AI, connected services, and autonomous systems is already well underway in many parts of the world. The last decade, in particular, has seen some key digital agriculture solutions "reach sufficient scale to become commercially attractive to investors and have a positive socio-economic impact on smallholder farmers"[7].

Estimates show that "IoT devices in the agriculture industry reached 75 million in 2020 helping farmers close the supply demand gap, by ensuring high yields, profitability, and protection of the environment."[8] AI, as a key technology, is "expected to reach 790 million USD by the end of 2023, growing at a CAGR of 21.8%"[9].

Much of this growth will be seen in developing countries. Research has shown that "the push to deploy digital tools in the last mile is strongest in structured value chains for cash crops, such as coffee, tea, cocoa and dairy"[10], many of which are key export revenue generators for developing countries. These countries tend to rely on agriculture for a comparatively higher portion of their GDP and employ more people in the sector.[11]

In the light of these developments, digital technologies like AI, connected services, and autonomous systems can advance the sustainability and resilience of agricultural production and, consequently, hold the key to achieving the Sustainable Development Goals (SDG) of the United Nations (UN).

The Focus Group on "Artificial Intelligence (AI) and Internet of Things (IoT) for Digital Agriculture (FG-AI4A)", will establish a forum that brings together stakeholders from around the world and from different backgrounds, to study and explore solutions and to advance pre-standardization in this field.

During the SG20 plenary that took place on 21 October 2021, it was agreed to establish a new ITU-T Focus Group on AI and IoT for Digital Agriculture (FG-AI4A) with the terms of reference as provided in Annex A, and with **ITU-T SG20: Internet of things (IoT) and smart cities and communities** as the parent study group.

ITU-T SG20 has significant expertise in studying and carrying out standardization work on the application of IoT and AI in smart cities and communities and agriculture.

It has already published well-received international standards on the topic of agriculture such as Recommendation ITU-T Y.4450/Y.2238: 'Overview of Smart Farming based on networks' and Recommendation ITU-T Y.2245: 'Service model of the agriculture information based convergence service'.

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[7] Phatty-Jobe, Abbie, et al. "Digital Agriculture Maps: 2020 State of the Sector in Low and Middle-Income Countries." GSMA AgriTech Programme, September 2020, www.gsma.com/r/wp-content/uploads/2020/09/GSMA-Agritech-Digital-Agriculture-Maps.pdf.

[8] IOT Solutions World Congress 2021. "IoT transforming the future of agriculture." www.iotsworldcongress.com/iot-transforming-the-future-of-agriculture/.

[9] Deloitte. "Transforming Agriculture through Digital Technologies." Jan. 2020, www2.deloitte.com/content/dam/Deloitte/gr/Documents/consumer-business/gr_Transforming_Agriculture_through_Digital_Technologies_noexp.pdf.

[10] Phatty-Jobe, Abbie, et al. "Digital Agriculture Maps: 2020 State of the Sector in Low and Middle-Income Countries." GSMA AgriTech Programme, September 2020, www.gsma.com/r/wp-content/uploads/2020/09/GSMA-Agritech-Digital-Agriculture-Maps.pdf.

[11] Deloitte. "Transforming Agriculture through Digital Technologies." Jan. 2020, www2.deloitte.com/content/dam/Deloitte/gr/Documents/consumer-business/gr_Transforming_Agriculture_through_Digital_Technologies_noexp.pdf.

Annex A: Terms of References: Focus Group on "Artificial Intelligence (AI) and Internet of Things (IoT) for Digital Agriculture" (FG-AI4A)

1. Context and Scope

In 2015, the UN adopted 17 SDGs, which should be achieved by 2030. Many of these goals, including SDG2 (zero hunger), SDG6 (clean water and sanitation), SDG8 (decent work and economic growth), SDG9 (industry, innovation, and infrastructure), SDG12 (responsible consumption and production), SDG13 (climate action), SDG14 (life below water) and SDG15 (life on land) are intimately intertwined with technological advances in agriculture.

Current figures indicate that nearly 690 million people worldwide (8.9% of the world population) are hungry.[12] Nearly 750 million (close to 1 in 10 people in the world) also experienced severe levels of food insecurity in 2019.[13] 2 billion people suffer from malnutrition[14] due to factors such as inaccessibility and unaffordability of nutritious food. [15] Economic downturns or slowdowns also lead to an increase in unemployment, whereby a reduction in wages restricts poor people's access to nutritious food. These trends are likely to be further amplified by the global COVID-19 pandemic.[16]

In addition, a rising global population means an ever-increasing global demand for food. Indeed, by the year 2050, the global population is on track to reach 9.7 billion people.[17] Some estimates show that to meet such growing food demand, global food production needs to grow by 70% in the next few decades, all while the agriculture sector faces several challenges.[18]

In addition to this growing demand for agricultural products, it is important to consider the environmental costs; this introduces the constraint of sustainability into the agricultural production in order to plan for future generations. Agriculture affects both the quantity and the quality of ground- and surface water. For instance, pesticides and fertilizers are a known cause of poor water quality [19]. Irrigation practices are becoming increasingly relevant. Therefore, to ensure that agriculture is sustainable, solutions must be found for precise application of pesticides and fertilizers and for efficient irrigation.

Furthermore, in many countries around the world, rural societies are facing problems related to aging populations, abandoned farmland and climate change. Despite the current trend reversal seen in some parts of the world due to COVID-19, it may still be the case that cities and their outlying areas will continue to attract people over time[20] due to the economic opportunities that they present.

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[12] FAO. "The state of food security and nutrition in the world." 2020, www.fao.org/3/ca9692en/online/ca9692en.html#chapter-Key_message.

[13] FAO. "The state of food security and nutrition in the world." 2020, www.fao.org/3/ca9692en/online/ca9692en.html#chapter-Key_message.

[14] Deloitte. "Transforming Agriculture through Digital Technologies." Jan. 2020, www2.deloitte.com/content/dam/Deloitte/gr/Documents/consumer-business/gr_Transforming_Agriculture_through_Digital_Technologies_noexp.pdf.

[15] Farming First. Rising Food Insecurity Linked to Economic Decline, Says New SOFI Report. 16 July 2019, farmingfirst.org/2019/07/rising-food-insecurity-linked-to-economic-decline-says-new-sofi-report/.

[16] FAO. "The state of food security and nutrition in the world." 2020, www.fao.org/3/ca9692en/online/ca9692en.html#chapter-Key_message.

[17] Scott, Dan. "Smart Farming & FoodTech Revolutionizes the Future of Food." Vontobel Holding AG, 2 May 2018, www.vontobel.com/en-ch/impact/smart-farming-the-future-of-agriculture-9097/.

[18] Scott, Dan. "Smart Farming & FoodTech Revolutionizes the Future of Food." Vontobel Holding AG, 2 May 2018, www.vontobel.com/en-ch/impact/smart-farming-the-future-of-agriculture-9097/.

[19] "Water for Agriculture — European Environment Agency," accessed September 21, 2021, https://www.eea.europa.eu/articles/water-for-agriculture.

[20] Pomeroy, Robin, and Ross Chainey. "Has COVID Killed Cities - or Can They Bounce Back?" World Economic Forum, 12 Nov. 2020, www.weforum.org/agenda/2020/11/cities-podcast-new-york-dead/.

Finally, it is important to mention that, although the number of people working in agriculture is expected to decline, "the sheer scale of the working poor in the sector, and the inherently dangerous and uncertain nature of agricultural work require that the world focus on addressing decent work deficits at all levels". Also here, automation and human-robot collaboration in agriculture production has the potential to significantly improve working conditions.

In conjunction, these circumstances highlight the importance of (and challenges related to) achieving zero hunger by 2030. Fortunately, technological advances are a tool that can help us to improve our management of agricultural production processes and achieve food security.

To address these challenges and opportunities, FG-AI4A explores the potential of AI, IoT, along with the development of technical reports and specifications to support data acquisition and handling, improves modeling of across spatiotemporal scales through extracting complex patterns (and gaining insights) from a growing volume of agricultural and geospatial data, provides effective communication and infers and recommends interventions for the optimization of agricultural production processes.

To achieve these ambitious objectives, FG-AI4A converges multiple stakeholders and experts from across the globe, building also on results of existing projects and cooperations such as IoF2020 and Atlas. Cooperation will be sought with the FAO's International Platform for Digital Food and Agriculture. Special effort will be made to support participation from low- and mid-income countries and those countries shown to be particularly impacted by these types of events (e.g., SIDS, LLDC, and LDC). Finally, FG-AI4A advances the efforts of the parent group Study Group 20 to advance technology for machine to machine communication and IoT, and the corresponding end-to-end architectures for, and mechanisms for the interoperability of IoT applications and datasets with a specific focus on digital agriculture use cases.

Therefore, the use of AI and IoT is needed to boost global agricultural output without the addition of more resources such as land acreage, water and human resources. This is referred to as digital agriculture.

Other related concepts include:

Precision agriculture is "an umbrella concept for IoT-based approaches that make farming more controlled and accurate…precision farming allows decisions to be made per square meter or even per plant/animal rather than for a field. By precisely measuring variations within a field, farmers can boost the effectiveness of pesticides and fertilizers, or use them selectively."[21]

Precision livestock farming entails farmers making use of "wireless IoT applications to monitor the location, well-being, and health of their cattle. With this information, they can identify sick animals, so that they can be separated from the herd to prevent the spread of disease."[22]

Controlled-environment agriculture (CEA) "is an approach where crops are grown indoor with an optimized use of water and space compared to conventional agriculture, while simultaneously controlling for factors such as light, temperature, humidity, CO_2 and nutrient concentration. *Vertical farming* is a good example, with a welcomed side effect. It enables food production closer to or in cities."[23]

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[21] Sciforce. "Smart Farming: The Future of Agriculture." 22 June 2020, www.iotforall.com/smart-farming-future-of-agriculture.
[22] Sciforce. "Smart Farming: The Future of Agriculture." 22 June 2020, www.iotforall.com/smart-farming-future-of-agriculture.
[23] Scott, Dan. "Smart Farming & FoodTech Revolutionizes the Future of Food." Vontobel Holding AG, 2 May 2018, www.vontobel.com/en-ch/impact/smart-farming-the-future-of-agriculture-9097/.

Smart greenhouses use IoT to "intelligently monitor as well as control the climate, eliminating the need for manual intervention. Various sensors are deployed to measure the environmental parameters according to the specific requirements of the crop. That data is stored in a cloud-based platform for further processing and control with minimal manual intervention."[24]

2. Objectives of the Focus Group on AI and IoT for Digital Agriculture (FG-AI4A)

The proposed Focus Group explores the potential of AI and IoT to support innovative practices for agricultural production. The Focus Group also studies any downsides of these technologies within this context, any barriers related to their use, best practices for their optimal deployment, and any other relevant topics.

As part of this effort, the Focus Group conducts an analysis of the use of AI and IoT in agricultural production in order to identify its current state (globally and regionally), key concepts, major trends, relevant gaps and issues in standardization activities related to this topic, and more, to derive use cases, to explore high level requirements and possible architectural approaches, to satisfy user needs of this lively sector. The focus group aims to publish the results of these efforts in various reports and case studies.

To achieve this, the FG-AI4A converges multiple stakeholders and experts from across the globe, serving as an open platform for experts representing ITU members and non-ITU members to quickly move forward, studies on technology, standards, and applications relevant to AI and IoT in agriculture.

Special effort will be made to support participation from low- and mid-income countries and those countries shown to be potentially most impacted by digital agriculture (e.g., SIDS, LLDC,and LDCs). Finally, the FG-AI4A advances the efforts of its parent group, ITU-T Study Group 20 in the areas of AI and IoT.

More precisely, the Focus Group's objectives include:

a) Promote the activities of this Focus Group for its pre-standardization work of eco-friendly AI and IoT technologies in agriculture;

b) Build a community of stakeholders and experts from around the globe to explore the use of emerging technologies for AI and IoT in agriculture;

c) Maximize synergies within this community to support the interlinked goals of the UN for a more food-secure abundant and agri-advanced future;

d) Identify projects related to use of AI and IoT in Agriculture and related services, precision farming, precision livestock farming, controlled-environment agriculture, smart greenhouses, vertical farming, digital agriculture etc. that would need future standardization etc.;

e) Develop a set of deliverables (e.g. technical reports, technical specifications, etc) related to eco-friendly AI and IoT technologies in agriculture, including (but not limited to):

- Terms, key concepts, framework;
- Intelligent infrastructure;
- Information collection;

[24] Sciforce. "Smart Farming: The Future of Agriculture." 22 June 2020, www.iotforall.com/smart-farming-future-of-agriculture.

- Data acquisition;
- Data interface, information transfer and network;
- Central decision-making and edge computing;
- Lightweight AI/ML (TinyML)
- Distributed Artificial Intelligence-as-a-Service (DAIaaS)
- Independent working;
- Robotics (UAVs and UGVs);
- Information and cyber security.

f) Study architectures, interfaces, protocols, data formats, interoperability, performance evaluation and more for AI and IoT in agriculture to develop mature and commercially valuable solutions;

g) Produce a gap analysis of standardization in the fields of AI and IoT in agriculture;

h) Identify current best practices in the overall field of AI and IoT in agriculture and build on these through study, research and expert consultation;

i) Establish liaisons and relationships with other organisations and projects which could contribute to the standardization activities for AI and IoT in agriculture;

j) Stimulate public engagement and international collaboration to put into practice the standard system of AI and IoT in agriculture, to help realize the potential for AI and IoT in agriculture to reduce poverty (SDG 1) and hunger (SDG 2) whilst also encouraging decent work and economic growth (SGD 8), industry, innovation and infrastructure (SDG 9), and sustainable consumption and production (SGD 12), combatting climate change (SDG13) for the benefit of life on land (SDG15).

3. Specific Tasks and Deliverables

a) Developing terminology and taxonomy for AI and IoT in agriculture, including the clarification on related terms and concepts, taking into consideration existing work;

b) Gathering information on initiatives, projects, and use-cases pertaining to AI and IoT in agriculture, to identify existing standards, best practices/findings as well as challenges for the adoption of AI and IoT in agricultural production processes;

c) Identifying areas where AI and IoT in agriculture can support the furtherance of overall use of digital technologies in agricultural production processes;

d) Drafting technical reports and specifications on using, AI and IoT to support data acquisition, data handling, data modelling, and data use, including real-time data monitoring and remote sensing, based on input from the use cases (e.g., digital twins of agricultural processes, data handling, data modelling, etc).

e) Analyzing and identify the standardization gaps related to AI and IoT in agriculture and develop a future standardization roadmap, taking into consideration the activities currently undertaken by other ITU groups, various standards developing organizations (SDOs) and forums;

f) Holding workshops/webinars that bring together stakeholders and experts, highlight ground-breaking activities in the area of AI, IoT—and standardization—for agricultural production processes, and facilitate recruitment of new Focus Group members. In addition, evaluating proposals of new use cases for inclusion in the subgroups.

g) Developing educational materials (e.g., online courses and pamphlets) in conjunction with other partners, which make the progress of the Focus Group accessible to all stakeholders and experts, in particular, those in developing countries.

4. Relationships

This Focus Group will collaborate with relevant entities, in accordance with Recommendation ITU-T A.7. These entities include the following: UN bodies, non-governmental organizations (NGOs), municipalities, policy makers, SDOs, industry forums and consortia, companies, academic institutions, research institutions and other relevant organizations.

The proposed Focus Group on AI and IoT for Digital Agriculture will collaborate with ITU study groups,

- ITU-T SG5 (WP2/5 on Environment, Energy Efficiency and the Circular Economy)
- ITU-T SG12 to leverage the P.1100-P.1199 series on communications involving vehicles
- ITU-T SG13 on Future networks (& cloud)
- ITU-T SG16 (Q21/16 on multimedia framework, applications and services and Q27/16 on vehicle gateway platform for telecommunication and ITS services and applications)
- ITU-T SG17 on security
- ITU-T SG20 (ITU-T Q2/20 and 4/20 on IoT use cases, requirements and data aspects related to digital agriculture)
- ITU-R SG4 on satellite services and ITU-R SG5 on connectivity for high precision navigation
- ITU-D SG1 and SG2
- ITU-T Focus Group on Environmental Efficiency for Artificial Intelligence and other Emerging Technologies (FG-AI4EE)
- ITU-T Focus Group on AI for Natural Disaster Management (FG-AI4NDM)

5. Structure

The proposed Focus Group may establish sub-groups if needed.

6. Parent group

The parent group of the Focus Group is **ITU-T Study Group 20**: Internet of things (IoT) and smart cities and communities (SC&C).

7. Leadership

See clause 2.3 of Recommendation ITU-T A.7.

8. Participation

See clause 3 of Recommendation ITU-T A.7. A list of participants will be maintained for reference purposes and reported to the parent group. It is important to mention that the participation in this Focus Group has to be based on contributions and active participations.

9. Administrative support

See clause 5 of Recommendation ITU-T A.7.

10. General financing

See clauses 4 and 10.2 of Recommendation ITU-T A.7.

11. Meetings

The Focus Group will conduct regular meetings. The frequency and locations of meetings will be determined by the Focus Group management. The overall meetings plan will be announced after the approval of the terms of reference. The Focus Group will use remote collaboration tools to the maximum extent.

The meeting dates will be announced by electronic means (e.g., e-mail and website, etc.) at least four weeks in advance.

12. Technical contributions

See clause 8 of Recommendation ITU-T A.7.

13. Working language

The working language is English.

14. Approval of deliverables

Approval of deliverables shall be taken by consensus.

15. Working guidelines

Working procedures shall follow the procedures of Rapporteur meetings. No additional working guidelines are defined.

16. Progress reports

See clause 11 of Recommendation ITU-T A.7.

17. Announcement of Focus Group formation

The formation of the Focus Group will be announced via TSB Circular to all ITU membership, via the ITU-T News log, press releases and other means, including communication with the other involved organizations.

18. Milestones and duration of the Focus Group

The Focus Group lifetime is set for one year from the first meeting with possibility of extension.

19. Patent policy

See clause 9 of Recommendation ITU-T A.7.