AI-BASED SOLUTIONS FOR INTER-SECTORAL DATA DRIVEN APPLICATIONS

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ABSTRACT

AMBITIOUS [1] aims at providing a fundamental technological infrastructure, which will offer advanced data aggregation and clean-up, analytics, AI-enabled forecasting and secure information exchange mechanisms, via a transparent computing continuum infrastructure, to be integrated with existing, mature services of SMEs, unleashing for them yet unforeseen functionalities and opening up new pathways of commercial exploitation. The envisaged fundamental infrastructure will be provided via the deployment of technological pillars, which will interact with existing infrastructure and services towards supporting the envisioned functionalities. This paper presents the considered use cases in AMBITIOUS and presents an envisioned AI-based framework for data driven applications.

KEYWORDS

5G; AI; digital health; intelligent living; IoT; precise agriculture; real-time monitoring; safety; smart water management, Unmanned Aerial Vehicles (UAVs).

1. INTRODUCTION

Several activities for the development of digital solutions based on 5G technology are currently taking off in many parts of Europe, giving businesses and consumers many opportunities for connecting and efficiently interacting with other business partners, service providers and social networks. New ecosystems and value networks will evolve and many business opportunities will occur [2].

At the same time, 5G is not only a new radio access technology offering higher data rates and lower latencies, but it is considered as an enabler for supporting cutting edge tools and applications in the new era of computing continuum, mixing cloud, edge and Internet of Things (IoT) resources [3-4]. 5G is being developed to be used in industry, especially for real-time applications like autonomous driving. To provide capability to industrial applications, the 5G network uses dedicated technologies like “slicing” [5] and “Edge computing” [6]. The resulting new technology platform enables developers to deploy their software not only centrally in the cloud and distributed in the end-users’ laptops and mobile phones, but also at the network edge. This new architecture paves the way for new business models, value chains and deployment models offering Small- and Medium-sized Enterprises (SMEs) to serve their clients even better with highly responsive applications and services. Systems could be designed to be more fault tolerant and robust using a combination of backend components deployed centrally and closer to the end-users.

The main goal of AMBITIOUS [1] is to deliver a fundamental technological infrastructure, providing advanced data aggregation and clean-up, analytics, Artificial Intelligence- (AI-) enabled forecasting and secure information exchange mechanisms, via a transparent computing continuum infrastructure, integrated with existing, mature services (of at least Technology Readiness Level 6 (TRL6)) of the relevant stakeholders (i.e., SMEs), unleashing for them yet unforeseen functionalities and opening up new pathways of commercial exploitation. The envisaged fundamental infrastructure is provided via the deployment of technological pillars, which interact with existing services towards supporting the envisioned functionalities. The purpose of a “pillar” is to provide the same generic functionalities to diverse services (demonstrated by a diverse set of specific use cases) as a concrete processing chain, aiming at avoiding unnecessary redundancy of resources and budget.

A variety of sectors are targeted including surveillance and safety, smart water management and precise agriculture. Our objectives are aligned with the smart specialization priority areas of the participating regions in the AMBITIOUS project. They are also long-term sustainable both from an ecological, social and economic viewpoint.

This paper presents the considered use cases and focuses on the adoption of AI-based solutions. The paper is organized as follows: Section 2 presents the motivation and the main objectives of AMBITIOUS. Section 3 presents the considered use cases. An envisioned AI-based framework for the AMBITIOUS use cases is investigated in Section 4. We conclude our remarks and present our future steps in Section 5.

2. MOTIVATION

We are facing new challenges to combat climate change, urbanization, energy production, workers' safety and many other issues. In addition, large segments of today's economy are going digital with new services and novel solutions. For the European Union (EU) to be able to cope with all these challenges, it is vital that European companies, especially the SMEs, are at the forefront of digitalization. New digital solutions offer possibilities to reduce the carbon footprint while improving the life of millions of people with increased safety and security, and better comfort, thus drastically enhancing living standards. By being in the forefront of the digital era, European companies will also be able to export solutions and services, being competitive in a world market framework.

The AMBITIOUS project aims to address challenges that are important to European companies to be competitive on the world market. By advancing their expertise in areas such as data analytics, AI, 5G, computing continuum and IoT, the European SMEs can both address challenges within Europe, but also grow and become more competitive in the global market sector. The AMBITIOUS project is focused on safety, smart water management, precise agriculture, and innovative digital health and wellbeing services, while at the same time it aims at improving competence and attractiveness in European SMEs. The core of the project is focused on scaling-up digital innovations, demonstrators of state-of-the-art technologies such as data analytics, AI-enabled prediction mechanisms, 5G, computing continuum and IoT sensing capabilities [7]. By providing several testbeds in Sweden, Finland, Italy and Greece, the participating SMEs will have first class access to multiple sites to perform early technology tests and, most importantly, to complete trials of digital products and services they intend to offer in the market.

AMBITIOUS project provides a virtual backbend of data aggregation, management and analytics, generic AI-enabled forecasting mechanisms, and data communication and exchange platforms, all residing at a transparent computing-continuum infrastructure [8]. All these fundamental technologies will then be exploited by properly designed use cases, which will integrate their own specialized mature services with advanced data analytics, prediction and secure communication capabilities. These use cases will be evaluated "in-situ" at appropriate regional/inter-regional demonstration sites that will act as our "success stories" and which will attract new stakeholders (i.e., SMEs) willing to exploit the proposed machinery for the sake of their own services and business plans. The next sections present in more detail the considered use cases.

3. AI-ENABLED DATA ANALYTICS AND FORECASTING

A typical scenario of a real-time monitoring and surveillance application of shared spaces and/or resources is to gather data (measurements), clean-up the inherent noise, visualize some kind of data analytics and then allow the human factor to make the well-thought and justified decisions towards improving the utilization of the entire system. We focus on the provision of the necessary computing resources and functionalities that would constitute a sophisticated data analytics engine, as well as an AI-enabled event forecasting module, which would be part of a sophisticated automated Decision Support System (DSS). This generic DSS platform, after being customized for a specific use case, would significantly assist the human controllers in making educated and justified decisions on the operation of the entire monitored system. Since all these functional requirements for providing advanced data analytics and AI-enabled forecasting services are typically computationally demanding, AMBITIOUS employs computing-continuum technologies that blend cloud infrastructures with edge devices and IoT sensing sources, for exploiting the ambient computational power but also keeping computations "as close as possible" to the data sources.

To better illustrate our rationale, we provide two indicative scenarios: (i) Pre-trained data, contributed from multiple sources (e.g., from several use cases with the same business profile), could be created at cloud level as "social capital" and then be disseminated to several edge devices of particular stakeholders (e.g., SMEs) to provide advanced classification or forecasting tasks for the purposes of their own use cases. (ii) Specific AI-enabled forecasting services (e.g., localized weather forecasting reports) might be of interest for diverse use cases (e.g., marina surveillance and smart agriculture).

These forecasting services would then run in a public cloud infrastructure, avoiding redundancy either in computational efforts or in costs, and then feed all the interested applications with real-time streams of predictions and emergency alerts. The considered use cases are discussed below.

3.1 Surveillance/Monitoring of Controlled Areas

This use case aims to integrate a mature IoT platform with an Artificial Intelligence Platform that spans from edge to cloud, in order to provide an AI-enabled forecasting prediction system, for marina surveillance and emergent incidents in real time. In this use case, images from digital cameras as well as information from various sensors (noise level, temperature and humidity measurement, etc.) provide the data necessary to identify unexpected presence – or activity – within the main area of a marina and predict potential incidents (fire, collision, future congestion, etc.).

The proposed smart marina demonstrator is based on an advanced IoT grid, provided by SAMMY IKE[1], including sensors, actuators and cameras with edge computing capabilities, able to collect, process and aggregate data from diverse data sources. The existing commercial platform brings in an existing visualization and monitoring set of services that provides real-time snapshots of the marina. The end-users (e.g., marina administrators, operators, safety offices, etc.) have access to all the necessary information about the vessel positions and their behaviour inside the harbour.

In the AMBITIOUS platform, the data generated for monitoring the marina will be collected, aggregated and persisted to a computing-continuum infrastructure, at which the envisaged data analytics engine and the prediction models are applied to provide meaningful feedback to the end-user, such as thorough analytics for the usage of the marina, prediction of short-term future incidents (e.g., potential collisions) and also long-term future incidents (e.g., availability of spaces in combination with current and future weather conditions or special events that might potentially be of interest to the customers of the marina).

A modern marina is a highly dynamic environment with a lot of traffic during peak periods. Digitalization of the marina processes and services is still at an early stage. Most of the existing ICT infrastructures offer monitoring capabilities of the marinas [9] and delegate the responsibility for event detection and decisions to personnel required for continuous monitoring of the entire operational area. On the other hand, more sophisticated services that detect events and predict the status and behaviour of customers in the marina based on historical data is still an open issue and would facilitate and improve the operation of modern marina facilities.

Currently, the existing platform offers limited intelligent features and products that would allow the prediction of critical events (e.g., collision detection, weather forecasting, etc.) in a marina and would elevate the levels of safety for the marina guests. Additionally, new services that deliver prediction of the marina traffic in short/mid and long term and will optimize berth allocation and resource utilization are not yet fully tested in operational environments. The main objective of this use case is to integrate the existing platform with the envisioned components developed within AMBITIOUS. Such an integration "reflects" in cost reduction and considerably improved services to the yachters and to the marina operators. The new components are a condition "sine qua non" that enable the enrichment of SAMMY's existing services portfolio. AI-enabled forecasting technology is utilized to produce semantically enriched information. The objectives of the new services and products developed are addressed by the following components:

- **UC1.1 – Detection:** On-demand image annotation (specific for every field area) for creating datasets to enable accurate object detection. Each application – demonstrator's requirements define the demand for high-resolution images (number, quality, etc.). The images are received from the sensing devices (e.g., IP drones) and are sent then to a dedicated server through wireless network. Consequently, the

[1] https://www.sammyacht.com/

set of images are annotated to create the necessary datasets to feed object identification algorithms (e.g., Detectron22, TensorFlow3, etc.).

- **UC1.2 – Open area surveillance:** Video streaming that is transferrable almost in real-time to a cloud-based infrastructure. A UAV (Unmanned Aerial Vehicle or drone) transmits close-to-real-time video streams to a second device within a specific range. Onsite edge computing methods improve the data processing efficiency and transmit them to a media server, where the operation can be visualized and events of interests will be identified (e.g., detection of water pollution).
- **UC1.3 – Berth allocation optimization:** The existing platform collects data related to berth reservation and usage and feed the AI-enabled berth usage prediction model that will be deployed. This prediction model is trained and configured to enable prediction of future requests for reserving berths from yachters. The marina is enabled to use its facilities in short/mid/long term and better manage required resources.

3.2 Smart Water Management

There is a need to monitor various types of water resources in real-time. Understanding environmental conditions through the IoT and Artificial Intelligence enhances our awareness of our surroundings, proving invaluable for predicting and monitoring such scenarios [10]. Online regional flood inundation forecasting in urban areas is crucial for city flood management, especially as flood disasters become more frequent [11]. Monitoring of water tanks and water distribution network (either domestic or for agricultural use) requires reliable data network and sensors as well as easy to use monitoring dashboard for end-users (for example employees of water treatment plants/harbors/other companies such as logistics). Another place, where real-time monitoring is needed, is related to storm water wells. Climate change and dense urban areas may cause city floods. To predict these, it is important to know how local precipitation impacts storm water wells' water level. Intelligent monitoring provides several benefits such as improved situational awareness and predictive maintenance capabilities, as well as urban planning to take account flood risky areas. However, building intelligent IoT based monitoring systems requires broad expertise from different domains and digital technologies (cloud platforms, mobile app development [12], data network, IoT).

The existing deployed solutions comprise of a constellation of pressure sensors installed throughout the network of water management. Prominent wireless technologies are used for collecting sensor values and present the overall state of the network in web dashboards. The administrators of the infrastructure are able not only to monitor the state of the water infrastructure but to control it as well through respective interconnected actuators that are able to control the flow of the water. However, more sophisticated mechanisms that detect and predict failures and water demands while they are highly expected from end-user, are still missing.

This use case aims to extend the existing solution and implement intelligent management tools for water supply and distribution networks. The derived tools are designed in such a way so that they can be applied to any level of an existing infrastructure (water collection, storage, urban network of pipes) and for any scope (potable water supply or irrigation). The purpose of such a solution is to give the ability to the administrators of the network (water utility or industrial user) for remote monitoring, enhanced with meaningful insights on the water consumption and how the network operates, in general. In this context, IoT devices (smart meters and actuators) are installed to interact with the water network infrastructure for data collection and water flow control.

AMBITIOUS platform brings in a certain added value: Novel edge and cloud computing services execute various critical tasks of the system, such as: (i) data collection; (ii) data persistence; (iii) AI algorithms for pattern recognition, abnormality detection and localization; (iv) remote control of devices, and; (v) visualizations.

A water management system handles data and information with a high level of heterogeneity (e.g., events of various criticality, time series data, device controls, etc.) that generate various Quality-of-Service (QoS) demands. The optimal allocation of these operators to the nodes of this edge-cloud chain is determinant for the performance of the system. Parallel operations, queuing delays, available hardware and network resources are

[2] https://github.com/facebookresearch/detectron2
[3] https://www.tensorflow.org/

factors that need to be optimized to serve the application's functional and non-functional requirements without jeopardizing the total cost.

The main objective of this use case is to take advantage of the collected data and feed novel AI operators that span to all the four categories of analytics, that is: (i) Descriptive analytics give a primary assessment of the data aiming to extract patterns from the water usage and detect unexpected behaviour based on historical data; (ii) diagnostic analytics drill down to identify the reasons behind these deviations (e.g., water leakage, water theft, etc.) and an accurate location where the abnormalities occur; (iii) based on data availability, predictive analytics are able to predict such events and facilitate their prevention, and finally; (iv) prescriptive analytics leveraged on all the aforementioned knowledge facilitate the automatic response of the system to the events.

AMBITIOUS develops and deploys new AI-enabled prediction services and data analytics services, hosted by an edge/cloud infrastructure, to allow event detection and reaction to be executed without depending on network availability and delays. The solutions build upon an existing IoT infrastructure equipped with pressure and water flow sensors installed throughout the water distribution network. Data collection mechanisms are responsible to gather and fuse the data for feeding AI models that are able to predict future water use for various time windows and detect abnormal behaviour of the network that might indicate critical events in water distribution network, such as leakages. The prompt detection of these events allows newly created decision support modules to intervene through the network of actuators and reduce the water waste. In particular, the objectives of the new services and products developed are addressed by the following components:

- **UC2.1 - Leakage detection:** This component collects pressure values from sensors of the water distribution network and, based on proper/expected behaviour, is able to detect abnormalities that indicate the presence of water leakage and estimate the location of the leakage. This facilitates the fast intervention and resolution of water management problems and finally improves the quality of service.
- **UC2.2 - Prediction of water and energy needs:** This component is trained (based on historical data) to predict the needs for water and energy on the upcoming period (short/mid/long). This functionality is offered as a service that will support administrators to foresee the future water/energy demands, adjust operational and service costs.
- **UC2.3 – Prediction of potential urban flood:** This component is trained to predict urban floods based on local precipitation and storm water wells' water level. This functionality is offered as a service that supports cities and property owners to foresee the potential city floods and improve situational awareness and take potential risk account in the future urban planning. Service costs charged from cities and property owners.

3.3 Precision Agriculture

Precision agriculture is a farming management concept based on observing, measuring and responding to variability in crops, aiming to increase yield and efficiency [13]. More yield from fewer resources while retaining high-quality standards is an equation that farmers worldwide are looking to solve. The digitalization of agriculture with real-time data insights and control enables more precise and efficient management of crops and livestock.

Currently, there is an established network of crops where sensor devices are deployed to monitor ambient and soil parameters. Such parameters regard air temperature/humidity, soil humidity, wind and solar radiation. The collected sets of data are stored and presented in real time to the producer, so as to have a clear overview on the climatic conditions of his cultivation. These data sets are utilized in collaboration with the agronomist to define an optimal irrigation plan. Irrigation is then controlled by a water management system comprised of water pipes and actuators that the producer can control remotely. While the existing solution facilitates the management of the cultivation, the producer is not able to predict how his irrigation plan combined with environmental conditions must be adjusted in future. Soil humidity along with ambient conditions are strongly related to the presence and growth of bacteria that might affect and deteriorate the production, in terms of volume and quality. Thus, early detection and/or prediction of plant disease will optimize the use of fertilizers and improve production.

This use case focuses on utilizing the smart devices and sensors under the existing IoT platform, enhanced with the sophisticated data analytics engine and an AI-enabled prediction module, to boost precision agriculture towards increased yields and efficiency. The IoT constellation encompasses all these variabilities by installing on site and integrate with new AI-enabled cloud services the appropriate sensors and actuators that monitor the

conditions of the cultivation. Such conditions are described by environmental conditions (e.g., temperature and humidity), soil humidity, light, irrigation patterns, etc. Moreover, the early detection of various phyto-pathological factors further benefits the crop in terms of volume and quality as well. Image acquisition and processing techniques are employed for capturing diseases in plants caused by pathogens (infectious organisms) and environmental conditions (physiological factors). The heavy tasks of image processing and the inference of the AI models are distributed among cloud and edge infrastructure aiming to deliver optimized use of resources with the adequate efficiency and performance of the application.

The integration of the new components with the existing platform brings in a certain added value: The new tools facilitate the entire operation of farming, thereby maximizing profits and minimizing excessive resource use. The adoption of such solution supports producers to become better stewards of the land by incorporating nutrient best management practices into their farming operation, while optimizing the use of resources (e.g., fertilizers and irrigation). Moreover, the exposure of the cultivation conditions and techniques to the end-user increases the traceability and the transparency of the agricultural product, thus reflecting to the increase of trust between consumers and producers.

All the necessary AI-enabled prediction and data analytics services are developed and hosted by an IoT/edge/cloud infrastructure aiming at deploying a computing-continuum approach for distributing data processing closer to the data source. Moreover, this use case utilizes the knowledge and expertise available in the consortium for incorporating drones in existing IoT infrastructures. Drones are utilized for scanning the area of interest and extract valuable information from image acquisition, processing and classification. This approach allows event detection and reaction to be executed without depending on network availability and communication delays. In particular, the new services are addressed by the following components, deployed and evaluated in the demonstration sites:

- **UC3.1 – Plant disease detection:** This component uses images captured by the respective equipment installed in drones to perform image processing and classification and detect the most common plant diseases that are present on the leaves of the plants.
- **UC3.2 – Crop irrigation optimization:** This component is responsible to give a detailed overview of the crop's irrigation. Based on historical data and current environment conditions, it predicts the water needs, soon. The benefits from this optimization are two-fold: (i) The producer gives his crop a more stable environment in terms of irrigation, thus allowing the delivery of a more consistent quality to the final product, and; (ii) optimized water management reflects a more efficient use of the water resources. This is maximized when the same water resources are shared among multiple producers. The AI-enabled prediction models generated in the context of this use case are based on the Open Neural Network Exchange (ONNX) open standard (where applicable) that allows framework interoperability for fast training, network architecture flexibility or inferencing on mobile devices.

4. AI-BASED FRAMEWORK FOR DATA-DRIVEN APPLICATIONS

The conceptual architecture of the IoT testbed which is under deployment is presented in Figure 1. A wide range of end-devices and sensors are integrated in the IoT platform. Such devices include cameras, ultrasound sensors, motion sensors, temperature / humidity sensors, energy consumption monitoring devices, etc. The devices use multiple technologies (WiFi, LTE/5G, high speed links) for communicating with the IoT platform. Monitoring data are sent to a common backend system with optimized cloud storage, via a LoRaWAN gateway. Additionally, the end users can connect remotely to the back-end system to have access to their data, as well as control their end-devices. For example, switching on/off lights, monitoring temperature and humidity, detecting motion, tracking power and energy consumption, etc. The envisioned AI-based framework will additionally enable to provide data analytics, as well as real-time data visualization to the end users. End-users are also enabled to create customized views for data visualization. For example, users are enabled to select the starting/ending point of the requested data, the duration (on an hourly/daily/monthly basis), etc.

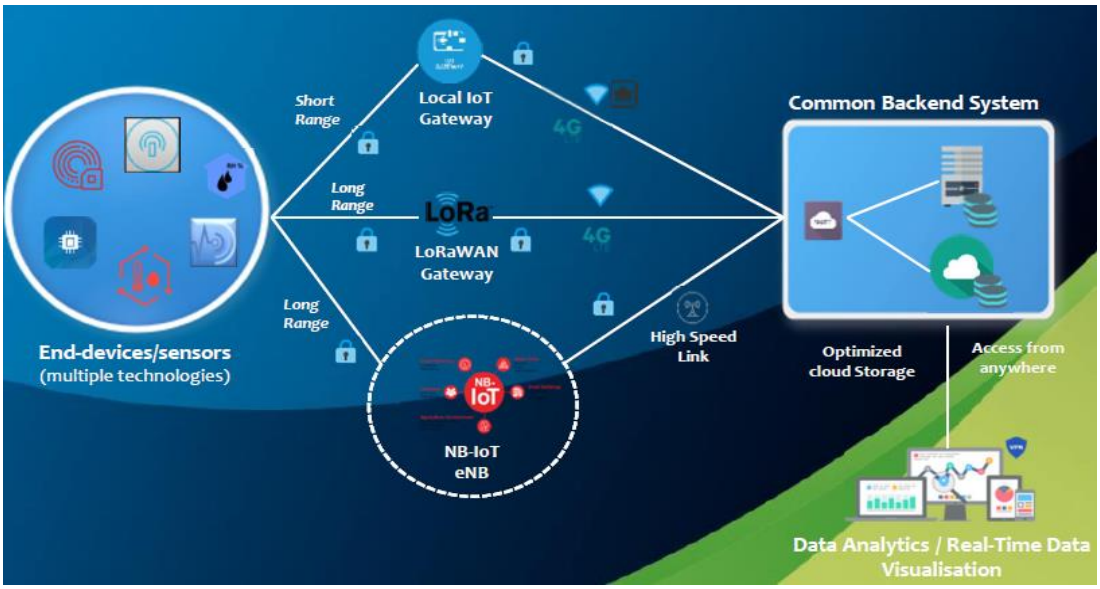
In addition, the considered platform will be able to support other functionalities and capabilities such as: monitoring (power/energy/voltage), energy management / control (remotely, on-demand), facility automation (based on predefined events/rules), push notifications at end-users' mobile devices, enhanced security and data privacy (VPN, SSL Certificates) and data visualization.

The underlying operating systems used are:

- *Analytics server:* Linux (Ubuntu/CentOS)

- *Gateway:* Rasbian
- *IoT devices:* Custom versions that vary.

Figure 1. IoT Testbed Overview.



A set of cameras are set in the context of each use case. Within the context of the AMBITIOUS project, enhanced AI mechanisms for image / object recognition and alerting will be deployed and tested (e.g., AI object recognition, smart cameras, augmented information and alerting, etc.). This service will also support the use of VR glasses by the administrator, being enabled to monitor several camera inputs on a virtual multi-windowed environment. Moreover, the platform users could receive alerts for emergency events (e.g., fire, harsh weather conditions, etc.) to inform the involved stakeholders. All the data received by the cameras and sensors will be sent via a gateway to a 5G router, using the commercial mobile network.

5. DISCUSSION

AMBITIOUS aims to support innovative SMEs with access to 5G test sites and a competence network. Furthermore, the planned inter-regional collaboration between Finnish, Swedish, Italian and Greek companies and universities will provide a multi-disciplinary competence body that will benefit each partner and enable faster technology development, field testing and shorten the time-to-market. In addition, this will be further strengthened by promoting the use of digital technologies such as Cloud, AI, 5G and IoT combined with, for example, UAVs, smart cameras and sensor systems.

For medium term benefits, this project will assist the participating companies to increase their digitalization competence and improve their technology capabilities. The project's results contribute to new innovations, products and solutions that will strengthen EU's competitiveness. For long term impact, the project aims to deliver results to the participating SMEs and society. The obtained results will improve work safety and the environment, while promoting inter-regional collaboration within the EU. This innovative environment, combined with access to 5G testbeds, will promote the development of new innovations and digital solutions in AI, UAVs, 5G, IoT, etc.

Our overall aim is to enable rapid enhancements for today's state of the solutions and deliver novel technological improvements that can be transformed soon into new products, services and ICT solutions.

ACKNOWLEDGEMENT

The paper has been based on the context of the AMBITIOUS ("Advanced CoMputing Continuum Solutions for Boosting DigITalization across European RegionS") European research project. This work has received funding from the European Union's Interregional Innovation Investments Instrument (I3) under Grant Agreement No.101115116.

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