APPLICATION OF SMART FARMING IN THE US OF FRESHWATER FISH CULTIVATION WASTEWATER FOR IOT-BASED SANSEVIERIA PLANT IRRIGATION

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ABSTRACT

Modern technology has brought significant changes to various sectors, including agriculture and environmental management. Challenges faced in plant cultivation include limited clean water sources and waste generated from various agricultural and aquaculture systems. The ornamental plant Sansevieria is one type of plant widely used in interior design due to its ability to improve air quality and its attractive aesthetics. By utilizing wastewater from fish ponds as an irrigation medium, it is hoped that these plants will not only be able to grow well and obtain adequate nutritional intake, but can also provide additional benefits in the form of reusing resources previously considered waste. The technology to be developed is based on the integration of the Internet of Things, which utilizes wastewater from freshwater fish aquaculture as an irrigation medium for ornamental Sansevieria plants. The method used is the Research and Development (R&D) method, a systematic approach that aims to develop, test, and refine a product through a series of gradual steps. One of the results of this research is a system that is able to demonstrate its potential in reducing dependence on clean water and providing new uses for aquaculture waste to maintain plant health efficiently.

KEYWORDS aquaculture, technology, agriculture, IoT

INTRODUCTION

Technological developments in the modern era have brought significant changes to various sectors, including agriculture and environmental management. One innovation with significant potential for optimizing natural resource use is the Internet of Things (IoT). IoT enables the integration of various smart devices to collect, monitor, and control data in real time (Hasibuan, 2023). This technology can be applied in the agricultural and plantation sectors to automate irrigation processes to ensure efficient water use and increase crop productivity.

One of the challenges faced in crop cultivation is the limited availability of clean water and the waste generated by various agricultural and aquaculture systems. In the cultivation of freshwater fish for consumption, such as catfish, aquaculture systems produce wastewater containing leftover feed and fish waste. If not managed properly, this waste can pollute the environment and cause ecological problems (Ahuja et al., 2020). However, the nutrients in aquaculture wastewater, such as nitrogen, phosphorus, and potassium, can be utilized as a nutrient source for plants (Kurniawan et al., 2022). Therefore, utilizing wastewater for crop irrigation can be a sustainable and environmentally friendly alternative solution. Through this effort, wastewater, previously considered a waste with no value, can be treated and reused, providing tangible benefits to the environment and society. In addition to reducing pollution and the burden on aquatic ecosystems, implementing this concept also supports the conservation of increasingly limited clean water resources. Thus, wastewater utilization is not merely an irrigation method but also represents a strategic step in realizing more efficient, ecological agriculture, in line with the principles of sustainable development.

The Sansevieria ornamental plant is a type of plant widely used in interior design due to its ability to improve air quality and its attractive aesthetics. This plant is known to absorb toxins and air pollutants and produce oxygen (Isnawati, 2021). By utilizing wastewater from fish ponds as an irrigation medium, it is hoped that these plants will not only grow well and obtain adequate nutrition, but also provide additional benefits by reusing resources previously considered waste. This utilization also serves as a concrete step in reducing environmental pollution, maintaining ecosystem balance, and supporting the concept of environmentally friendly, sustainable agriculture.

This system uses various sensors such as the DHT22 sensor to measure temperature and humidity, a soil moisture sensor to detect soil moisture, and a pH sensor to determine the acidity level of pond wastewater that will be channeled as an irrigation medium for ornamental plants. Data collected from these sensors will be processed in real-time through a microcontroller such as NodeMCU, which will automatically control the water pump based on the detected conditions. With this system, plant watering becomes more efficient and aquaculture wastewater can be utilized properly.

The pump will activate and drain pond wastewater based on the pH of the catfish aquaculture pond reading above the ideal value of 7.5, this is to help regulate the quality of the pond water pH better. In addition, if the sensor detects that the temperature around the plants is read above 29°C accompanied by the soil moisture of ornamental plants is below 50% RH, which indicates that the soil is too dry, the system will also automatically drain water from the catfish pond to water the plants. The pump will turn off when the soil moisture reaches 80% RH to anticipate excessive soil moisture.

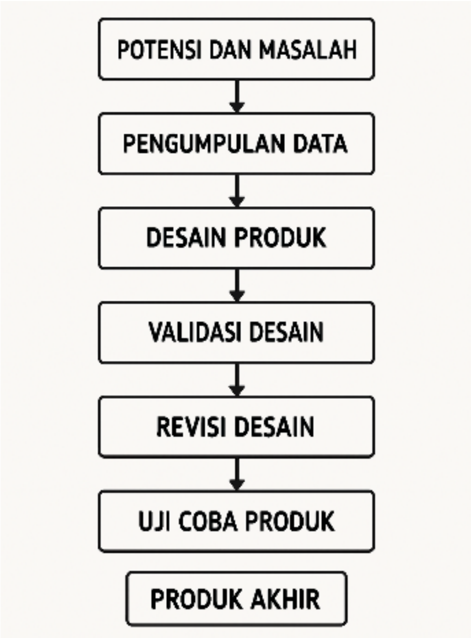
The problems that can be summarized from the explanation above regarding the use of IoT technology in automatic irrigation systems include;

1. By collecting real-time data on temperature, air and soil humidity, and the pH level of pond water, an IoT-based irrigation system can ensure that plants receive the right amount of water at the right time and that the pH of the pond water is maintained.
2. Utilizing wastewater as an irrigation medium not only saves the use of clean water and is an environmentally friendly solution, but also provides an additional source of nutrients for ornamental plants such as nitrogen, phosphorus, and potassium.

Based on the points outlined above, an Internet of Things (IoT)-based technology was designed that utilizes wastewater from freshwater fish aquaculture as an irrigation medium for Sansevieria ornamental plants. This technology is expected to not only be a breakthrough in the field of water resource management, but also provide an innovative, practical, and environmentally friendly solution. Through the implementation of the IoT system, the process of monitoring, controlling, and regulating irrigation can be carried out automatically and more efficiently, thereby supporting the optimal growth of Sansevieria plants while reducing the potential for environmental pollution due to improperly managed aquaculture waste disposal. Thus, the application of this concept not only provides direct benefits to the ornamental plant farming sector but also creates added value through more sustainable fishery waste management.

RESEARCH METHOD

The Research and Development (R&D) method is a systematic approach aimed at developing, testing, and refining a product through a series of gradual steps. Borg & Gall (1983) outlined the R&D stages as follows.



Source: (Waruwu, 2024)
Figure 1. Research and Development (R&D) Method

1. Potential and Problems
   The initial stage is to identify needs or problems that are worth researching and developing solutions for.
2. Data Collection
   The process of searching for supporting information from primary and secondary sources to strengthen the background and development needs.
3. Product Design
   Create an initial design of the product to be developed, both visually, technically and functionally.
4. Design Validation
   Product designs are tested conceptually through expert or practitioner opinions to assess the feasibility and suitability of the design.

5. Design Revision
   Make improvements and refinements to the design based on input from the previous validation process.
6. Product Trial
   Implement the product in prototype form and test it directly to evaluate the effectiveness, efficiency, and quality of the product.
7. Final Product
   The product is refined and prepared as a final product ready for use or proceeded to the wider dissemination and implementation stage.

RESULT AND DISCUSSION

1. Potential and Problems

a. Potential

The development of an IoT-based automatic irrigation system has significant potential to support water efficiency, save labor, and monitor plant environmental conditions in real time. In this research, the system was developed using fish pond wastewater, which inherently still contains nutrients beneficial to plants. Utilizing this wastewater not only contributes to water resource efficiency but also supports the principles of sustainable and environmentally friendly agriculture.

A web dashboard allows users to remotely monitor system conditions, sensor data, and set sensor thresholds. This system allows users to efficiently control irrigation. By combining IoT technology with the concept of wastewater recycling, this system has the potential to be a practical solution to support ornamental plant productivity, particularly at the household level, in urban farming, or even in integrated agricultural development.

b. Problems

Wastewater from fish farming is often disposed of without further use. According to research by Yusuf and Rachman (2023), this wastewater contains nutrients that can potentially support plant growth. On the other hand, conventional irrigation processes are generally carried out manually without considering real-time soil conditions, making them less efficient and risking drought or excess water. The limited application of IoT-based technology and the absence of remote monitoring and control systems are obstacles to creating adaptive and sustainable irrigation systems. These issues drive the need to develop intelligent, efficient, and environmentally friendly automated irrigation systems.

2. Data Collection

Data collection in this study was carried out using three main methods, namely literature study, observation, and documentation.

a. Based on the results of the literature study method, several important pieces of information were obtained that support the design of an IoT-based automatic irrigation system. Fish pond wastewater is known to contain nutrients beneficial to plants such as nitrogen, phosphorus, and potassium, as evidenced by a study by Ahuja, Sharma, and Mehra (2020) entitled "Potential of fish waste as organic fertilizer in sustainable agriculture." Therefore, this wastewater can be used as an alternative environmentally friendly watering medium. In terms of plant selection, a study conducted by Isnawati (2021) entitled "Sansevieria plants as absorbers of indoor air pollutants" showed that sansevieria plants have the ability to filter air and adapt well to various environmental conditions, thus being chosen as the object of watering in this study. For the measurement and monitoring system, the results of an automation and monitoring study of environmental parameters by Anshori and Effendi indicate that soil moisture and air temperature sensors such as the DHT22 and soil moisture sensors can be implemented in an IoT-based automatic irrigation system. In addition, the use of the ESP32 microcontroller was chosen based on the results of a study on Arduino-based soil moisture monitoring and IoT in horticultural plants by Sari & Hidayat (2024), which stated that the ESP32 has a greater number of analog pins compared to other microcontrollers such as the Arduino Uno. This greater number of analog pins allows the system to connect more than one analog sensor simultaneously, such as a pH sensor and a soil moisture sensor. Readings of multiple analog sensors can be done directly and efficiently, thereby simplifying the hardware circuit, reducing programming complexity, and speeding up the system's response time to changes in environmental conditions.

b. The observation method was conducted directly at the researcher's home as a potential location for the system's implementation. This location was selected based on the presence of a freshwater fish pond and sansevieria plants, which were the objects of watering. Observations included:
   1) Characteristics of pond wastewater (color, clarity, initial pH),
   2) Condition of the plants to be watered,
   3) Availability of infrastructure such as electricity and internet access.

c. To support the validity of the observation results, the researcher documented the environment in the form of photographs of the observation location. Documentation includes:
   1) A freshwater fish pond, as a source of wastewater to be used in the irrigation system. The pond water was observed for clarity, color, and initial pH.
   2) Sansevieria plants, as the irrigation test subjects. These plants were chosen for their ecological benefits as air filters. Photos were taken to illustrate the number, placement, and condition of the plants prior to the system's implementation.

3. Product Design

The design of this automatic irrigation system is carried out adaptively and flexibly, so that it is developed into an innovation that is more relevant and responsive to users.

a. System Administrator Flowchart

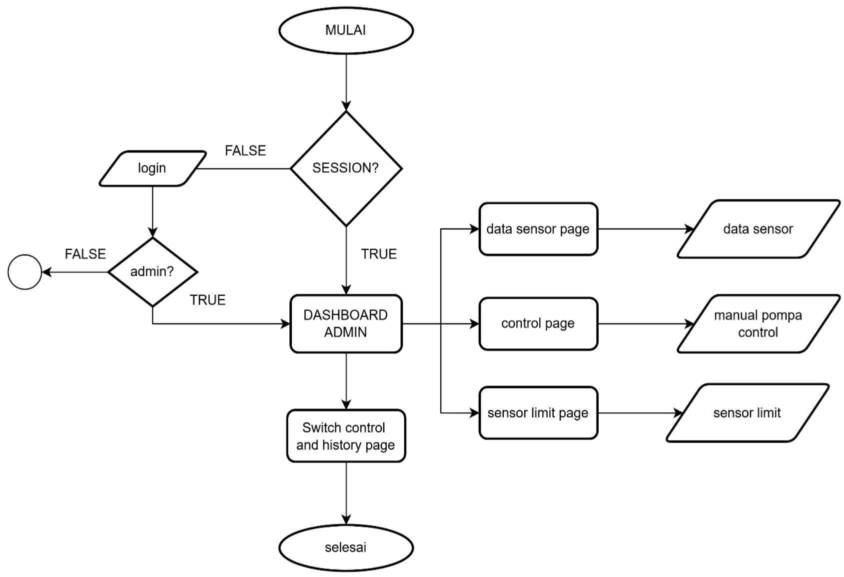


Figure 2. System Administrator Flowchart

b. User System Flowchart

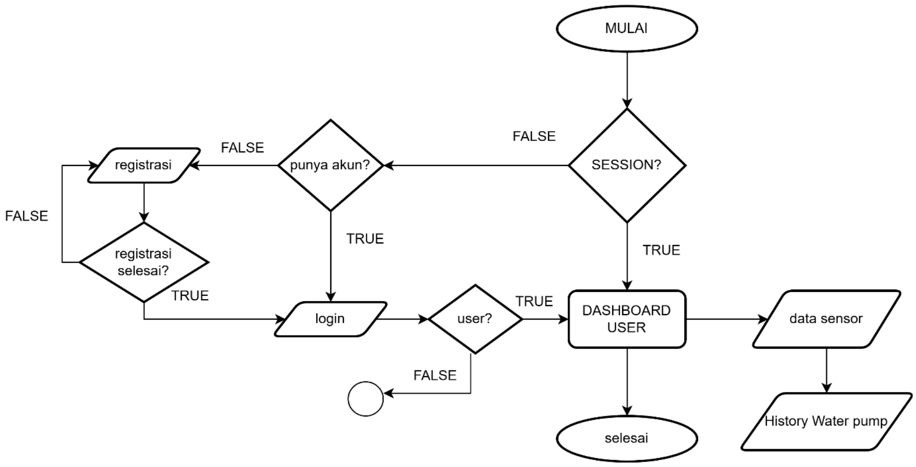


Figure 3. User System Flowchart

c. Context Diagram

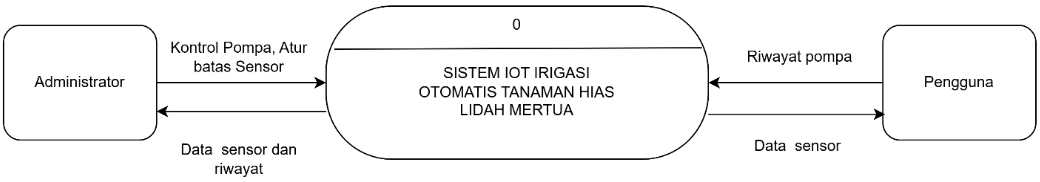


Figure 4. Context Diagram

d. Hierarchical Diagram

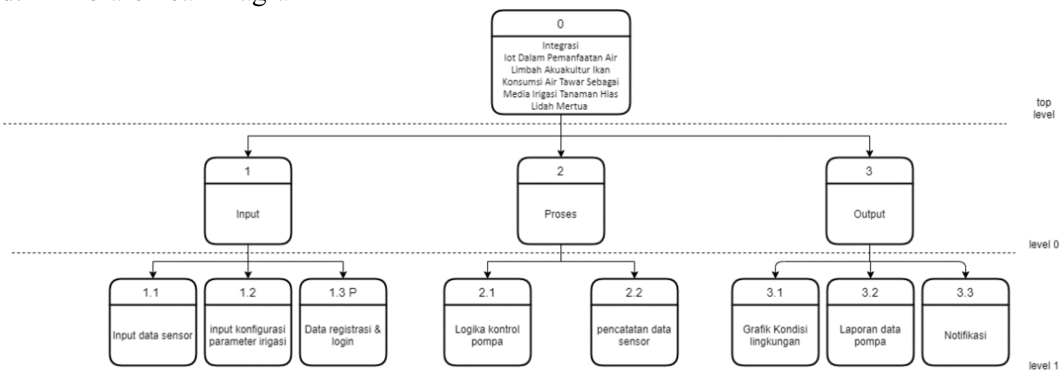


Figure 5. Hierarchical Diagram

e. Data Flow Diagram

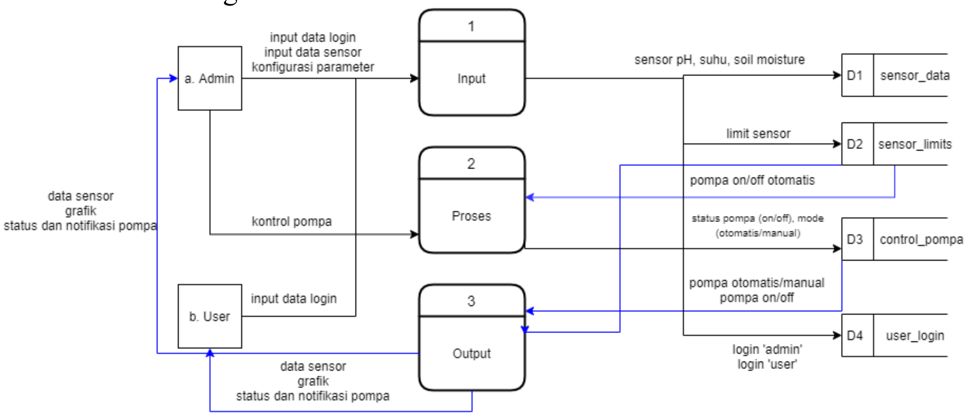


Figure 6. Level 0 Data Flow Diagram

f. Database Design

Storing data in an application requires a database with several tables, while the database itself is a collection of interrelated files indicated by a key.

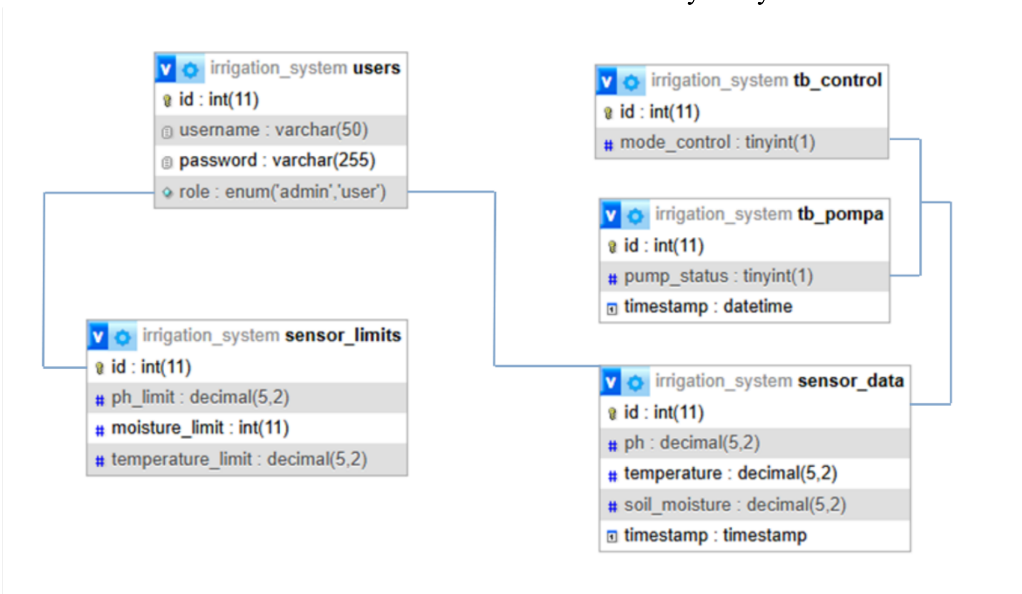


Figure 7. Relationships Between Tables

g. System Display

Login display, on the page the user must enter the previously registered Username and Password to access the system.

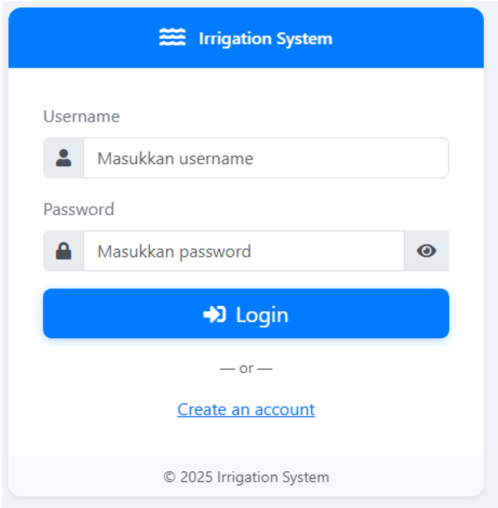


Figure 8. Login View

h. Tool Design

The following is a tool design for an IoT-based automatic irrigation system with wastewater that has been created:

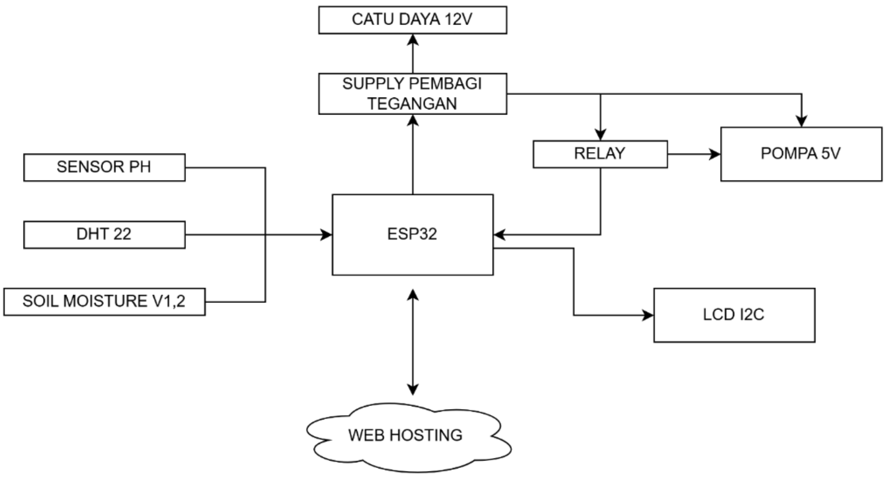


Figure 9. Tool Design

4. Design Validation

Design validation in system development is carried out to ensure that the developed automatic irrigation system meets the research objectives and functional requirements of the system. Validation is carried out through discussions and consultations with the supervisor regarding the system workflow design, sensor selection, automatic/manual control logic, and the web dashboard interface. Some of the components validated include the system flow diagram, sensor limit configuration, and user interface display. This process aims to ensure that the system design is feasible for implementation, has an appropriate logical structure, and can operate stably in real-world conditions.

5. Design Revision

After design validation, several adjustments were made to refine the system before moving on to implementation. Revisions were made based on feedback from the supervisor, including adding a sensor limit configuration feature via the dashboard, improving the sensor information display on the LCD, and optimizing the pump control logic to utilize more than one parameter (not just pH and soil moisture but also temperature).

6. Program Testing

In the testing stage of this IoT-based automatic irrigation system, the author applied the black box testing method to verify that each feature and function of the system has run according to the designed needs and specifications.

Table 1. Program Testing

No	Features/Modules	Type of Unit Tested	Results
1	Login Menu	Enter username and password for access as admin or user	Success
2	Registration Menu	Users can register a new account for access.	Success
3	Dashboard Menu	Displays the latest sensor data, environmental parameter development graphs and pump status.	Success
4	Sensor Data Menu	Displays a table of sensor measurement results data in real-time.	Success
5	Manual Pump Control Menu	Users can control the pump manually if manual mode is activated	Success
6	Sensor Limit Menu	Admin can set and change sensor threshold limits	Success
7	Pump Automation System	The pump can turn on and off automatically based on sensor data and sensor limits.	Success
8	API and Database	The system can store and retrieve sensor data, pump control, and users well.	Success

7. Final Product

After undergoing testing, both functionally and through inter-device connectivity, the entire data transfer and retrieval process between the microcontroller, server, and irrigation equipment ran stably. The irrigation system can operate both automatically and manually, and allows users to monitor and control it remotely using only an internet-connected device. This IoT-based automatic irrigation monitoring and control system can be accessed through a browser at https://wadahinovasi.com/irigasi_air_limbah.

CONCLUSION

1. The results of the prototype testing of this system demonstrate that the innovative IoT integration for wastewater-based automatic irrigation is a useful and functional concept. The ultimate outcome is a system that demonstrates its potential to reduce dependence on clean water and add new value to aquaculture wastewater to efficiently maintain plant health.
2. Based on the results of functional testing using the black box testing method, this IoT prototype has run according to its functional design. All key features tested, from user login, data monitoring on the dashboard, manual pump control, to automation logic based on sensor parameters were successfully verified with a "Success" status. This indicates that the prototype can reliably carry out its designed tasks.
3. This system has aspects that could be maximized for further development. For example, the control logic is still static, relying entirely on thresholds set by the administrator. To maximize this, the system has the potential to be developed with more dynamic or intelligent logic, such as using historical data for predictions.

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