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3-Wheel Omnidirectional Warehouse Automation Solution

Authors: Zorawar Singh Gulati [(1)], Reetu Jain [(2)]

[Institutional Affiliation(s)]
[(a)] Shikshantar Sr. Secondary School, W 1/9 1st floor DLF Phase 3, Gurgaon 122002
Email id: zorawarsingh1104@gmail.com

[(b)]Supervisor, On My Own Technology Pvt. Ltd., 2A, Pace House, 7 Swastik Society, Gulmohar Road, Vile Parle West, Mumbai - 400049, India.
Email-id: reetu.jain@onmyowntechnology.com
ORCID: 0000-0002-7199-2823

Abstract

Robotics is taking over automation. Nowadays robots can be found in all industries for various different purposes. One of the biggest fields where robots are used in Warehouse management. Robots are used to manage big warehouses without any help. There are many different technical solutions used for warehouse automation like Swarm Robotics, Magnetic Taping based Line Following Robotic systems, Omni Wheel Robots etc. My solution is a smart and efficient 3-wheel omnidirectional robot solution for warehouse management. Today, in the industry, Omni-directional solutions have 4 which hinder the efficiency of handling inventory. I have designed a 3-wheel Omnidirectional robot with a robotic arm to help sort and handle inventory. It manoeuvres and tracks its position with the help of a gyroscope sensor and an ultrasonic sensor-based mapping system. The two ultrasonic sensors are placed perpendicularly and are mounted on the stepper motor which keeps them straight while the robot takes turns or rotates in any direction. This method enables the robot to stay straight at all times. By staying straight, this robot does the same task while using two motors less than the present solution. It works on the Arduino microcontroller and C++ Programming and the algorithm works on the basic principles of trigonometry and the Cartesian plane. I believe that this system will decrease the cost of warehouse robotics, will reduce energy consumption and will increase the efficacy of the task

Keywords: Warehouse Automation, Omnidirectional, Warehouse Handling, Warehouse Management

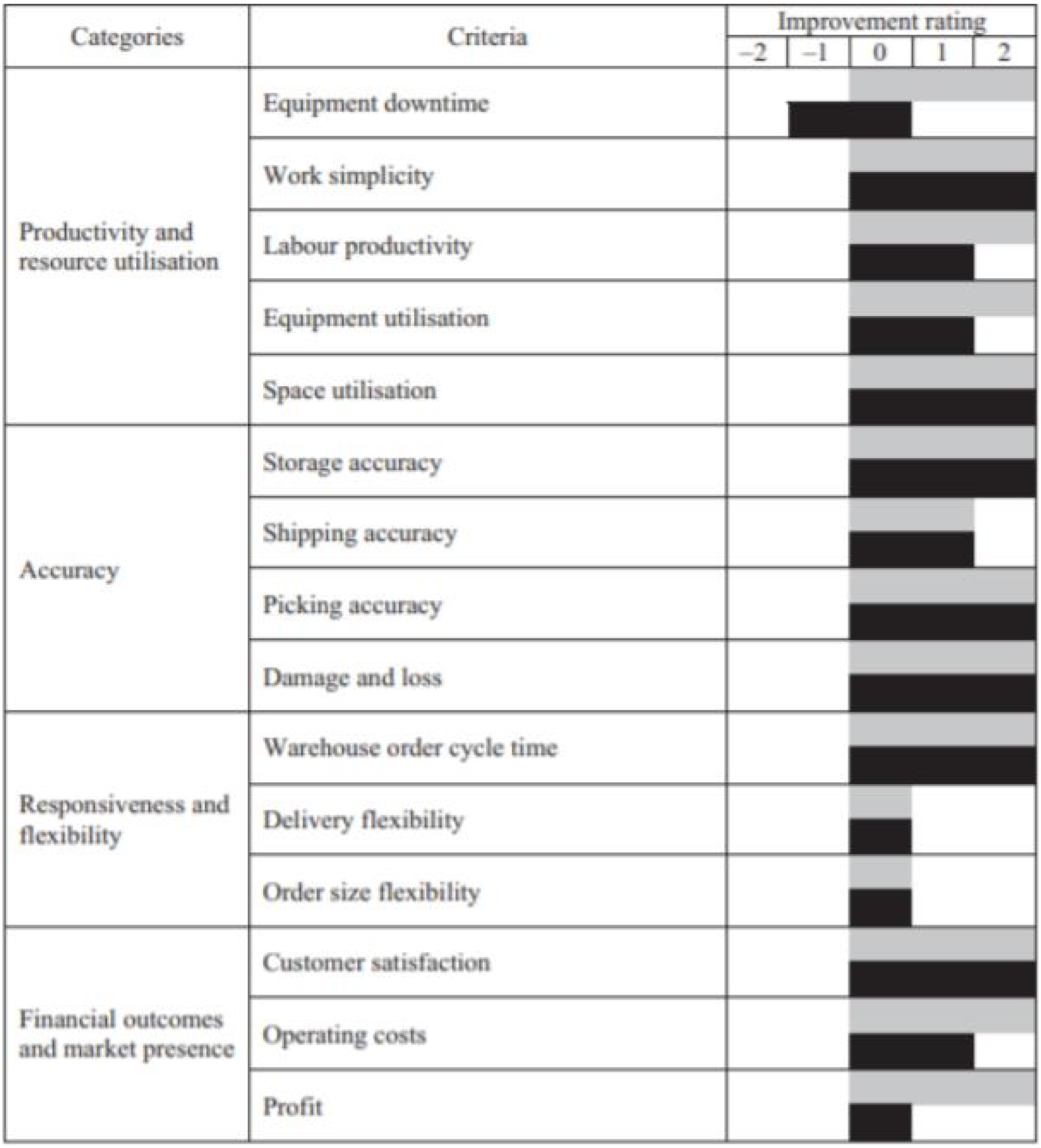
INTRODUCTION

Warehouse operations tend to be labour-intensive and require large spaces and management to cater for the needs of the ever-growing e-commerce industry. These operations require intensive labour which is often challenging to attain. This is where warehouse automation technology comes in. Over the past few decades, engineers have worked towards integrating modern technological advancements like artificial intelligence and machine learning. Along with eliminating the need to hire and manage labour, it also cuts costs down by about 70%. Primarily, artificial intelligence is divided into two branches – augmentation and automation. Augmentation deals with assisting humans with their daily tasks and automation carry out work without human intervention. Mainly all warehouse systems are automated and require no human interference. These systems are specialised to perform numerous tasks to automate warehouse processes. In the last decade, warehouse automation has developed rapidly, which has been aided by the rise of autonomous vehicle-based storage and retrieval systems. These systems use racks with aisles and deploy autonomous shuttles at each level in each aisle and are transported vertically with the help of lifts. A new generation of automated guided vehicles (AVGS) has recently been introduced. They normally follow magnetic stripes or a track laid out in a warehouse. AVGs that don't have a designated track are equipped with scanners and a mapping system of the layout of the warehouse. Along with the advantage of working 24/7, common AVGs only require only 8 minutes to recharge, which means they are out of commission for only short periods of time.

In an automated retail warehouse, suppliers unload their own trucks and feed the pre-announced pallets to a check-in conveyor. The pallets are then stored in an Automatic Storage and Retrieval system. When a certain product is requested, the pallet is offloaded and automatically detached. The loose cases are then often put on trays to ease manipulation and are stored in smaller Automatic Storage or Retrieval systems. When the store order arrives, the cases are retrieved and sequenced, and mixed-case palletizers build the pallets or roll-cages in a store-specific sequence that allows rapid shelving in the store.

The table below shows how the implementation of an automated storage and retrieval system along with an automated warehouse management system affected different aspects of a company's productivity and resource utilisation.

Improvement ratings of economic performances of two companies in 2021



As seen from the table, the warehouse managers from both companies reported an improvement in most of the criteria.

Research on automated, or even robotized, warehouses is not yet abundant. With the rise of new technologies, new questions arise and need answering. New models must be made to evaluate the performance of the systems and aid in answering design and management questions.

LITERATURE REVIEW

In the paper 'An accurate and efficient navigation system for omnidirectional robots in industrial environments, Christoph Sprunk discusses the navigation systems of omnidirectional robots in industrial environments. The solution presented uses dedicated modules for localisation, mapping and trajectory generation[1]. Patrick F. Muir in 'Kinematic Modeling for Feedback Control of an Omnidirectional Wheeled Mobile Robot' showcases the kinetic modelling of omnidirectional wheeled mobile robots and applies his methodology to a prototype being developed at the Robotics Institute of Carnegie Melon University. The solution uses a rectangular four-wheeled wheelbase and provides omnidirectional mobility independently and simultaneously in the X and Y axis[2]. 'Modeling and assessing of Omni-directional Robots with Three and Four Wheels' by Helder P. Oliviera, presents the mechanical configurations of three and four-mecanum-wheeled omnidirectional robots using all axis, and relevant velocities and forces. The paper conveys how these robots provide superior mobility and efficiency compared to conventional mobile robot solutions[3]. 'Tracking of Warehouses Robots Based on the Omnidirectional Wheels' by Alexey Zalevsky is based on experiments conducted on robot platforms that use four-wheeled omnidirectional wheels and a basic electronic control system[4].
'2D path control of four Omni wheels mobile platform with compass and gyroscope sensors' by Shiuh-Jer Huang, along with discussing the kinematics of a four-wheeled mobile platform, also introduces a sensing module using gyroscope sensors for basic localization[5]. 'The Rise of Automation and Robotics in Warehouse Management' by Amandeep Dhaliwal presents the advantages of automated storage and retrieval systems in warehouse management and discusses the rise of automation in e-commerce industries[6]. 'Path planning of the Omni-directional mobile vehicle in warehouse environment' by Jiang Zhao proposes an algorithm for the path planning of an omnidirectional robot in a storage environment to improve safety and stability. The algorithm helps in reducing the risk of collision in these environments[7]. 'Three Omni-Directional Wheels Control on a Mobile Robot' by F. Ribeira discusses the advantages of a three-wheel omnidirectional robot over a traditional two-wheeled robot. They discuss the kinematics of a three-wheeled omnidirectional bot used in RoboCup, a robotics competition where traditional two-wheeled robots are normally used and how the three-wheeled solution outperforms it.

Advantages of Warehouse Automation

Increased Productivity

Warehouse automation increases productivity. Automation allows doing more with less.

- Increased warehouse throughput
- Reduced labour and operational costs
- Reduced handling and storage costs
- Reduced human error

All the benefits indicated above are easy to identify as direct costs. The nonvalue-added tasks can be automated, while the value-added functions can be improved thanks to digital or physical automation.

Increased Efficiency

The latest automation technologies like mobile robots are fast and easy to deploy compared to traditional technologies like conveyors.

- Better scalability and flexibility
- Optimized warehouse space
- Improved order fulfilment accuracy
- Monitor and reduce energy use

The newest market trends like Mobile Robots-as-a-Service allow you to add or remove robots depending on your needs, so permit to react faster to demand variations.

Greater Inventory Control

Managing inventory, especially across multiple locations, can quickly become overwhelming and time-consuming when using manual methods. However, an automated inventory management system uses modern software to reduce routine stock counts and tracking time.

- Reduced stockout events
- Reduced inventory loss

Improved Customer Satisfaction

The automation of the warehouse benefits customers. Cost savings, customized solutions, fast and assured deliveries, and fewer mistakes, and damages are how customer satisfaction is enhanced.

- Fewer shipping errors
- Improved customer service
- Faster deliveries

PRESENT SOLUTIONS

Amazon Robotics Kiva Robots

Amazon has deployed 520,000 mobile drive unit robots in its distribution and fulfilment centres, the main ones being goods-to-person robots. They help with the maintenance of the conveyor system and the processing of orders. With the help of this system, humans can pack around 400 products instead of just 100 without these machines. Their autonomous mobile robot fleet is continuously optimized to increase package handling and delivery efficiency.

Stretch by Boston Dynamics

Boston Dynamics, the global leader in mobile robotics, has announced Stretch, its newest robot designed specifically for warehouses and distribution centres, is now available for commercial purchase. Part of a new generation of mobile robots, Stretch is one of the most advanced robots in the world today.

Stretch is a versatile, mobile robot that unloads floor-loaded trailers and containers for safer and more efficient warehouse operations. The robot works with a wide range of package types and sizes, from standard brown to highly graphical boxes, and can handle cases up to 50 pounds. With advanced mobility and a footprint, the size of a pallet, Stretch is built to manoeuvre in and out of trucks and tight

Industrial Robotics by Toyota

Automated Storage and Retrieval Systems by Toyota offer an automated solution that can improve material handling efficiency in both manufacturing facilities and distribution centres by eliminating the need for unnecessary trips down storage aisles and wasted movement in between widely placed racking, saving storage space and floor space. Highly integrative with forklifts already in use, ASRS systems use horizontal and vertical storage carousels to move various loads automatically to single or multiple retrieval locations, where a forklift or other piece of material handling equipment can move them to their next location. Monitoring and managing your inventory with RFID and computer-controlled systems occurs with real-time data integration, so moved loads are recorded automatically and storage audits can be reduced.

OUR SOLUTION

Our automated warehouse management system works towards energy conservation and efficiency. It works on an ultrasonic sensor mapping system and gyro sensor position detection with three omnidirectional wheels. The two ultrasonic sensors are placed perpendicularly and are mounted on the stepper motor which keeps them straight while the robot takes turns or rotates in any direction. This method enables the robot to stay straight at all times. By staying straight, and by having less motors compared to the present solutions, its energy conservation and efficiency are increased.

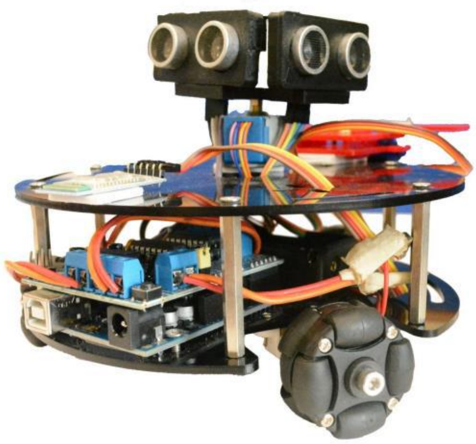
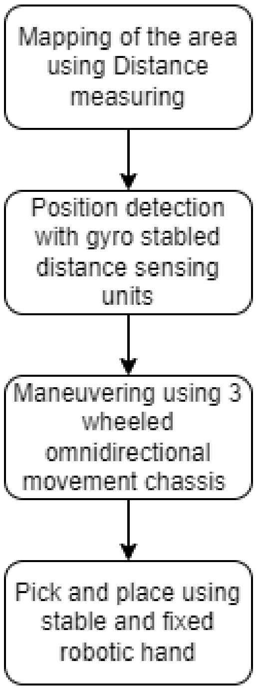


Fig. Our Prototype

It uses an Arduino UNO as its main controller, an L293D as a motor driver and three N20 100 RPM 6V DC Motors. It is powered by two 3.7V batteries and uses two HC-SR04 Ultrasonic Sensors along with one MPU6050 Gyroscopic Sensor.



PROTOTYPE

The prototype is the scaled model of the original prototype, the robot is based on the Arduino microcontroller, which is powered by 4 AA batteries, the prototype uses the dc motor with the feedback mechanism that is directly feeding to the controller, for positioning the in the X, Y plane two ultrasonic sensors are used that maintain the X, Y coordinates using the external gyro sensor attached to the robot, the detailed block diagram of the prototype is shown below

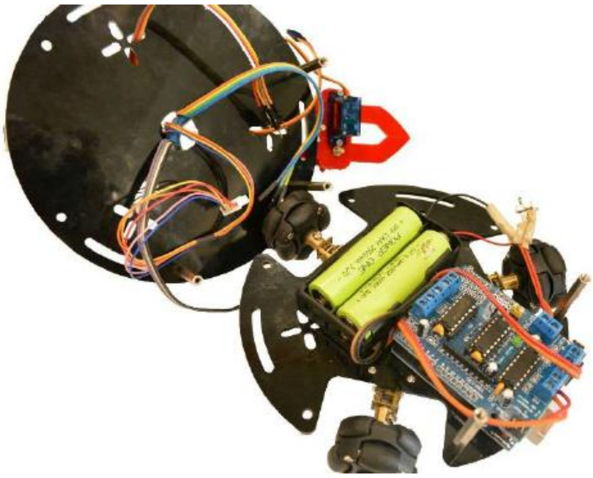
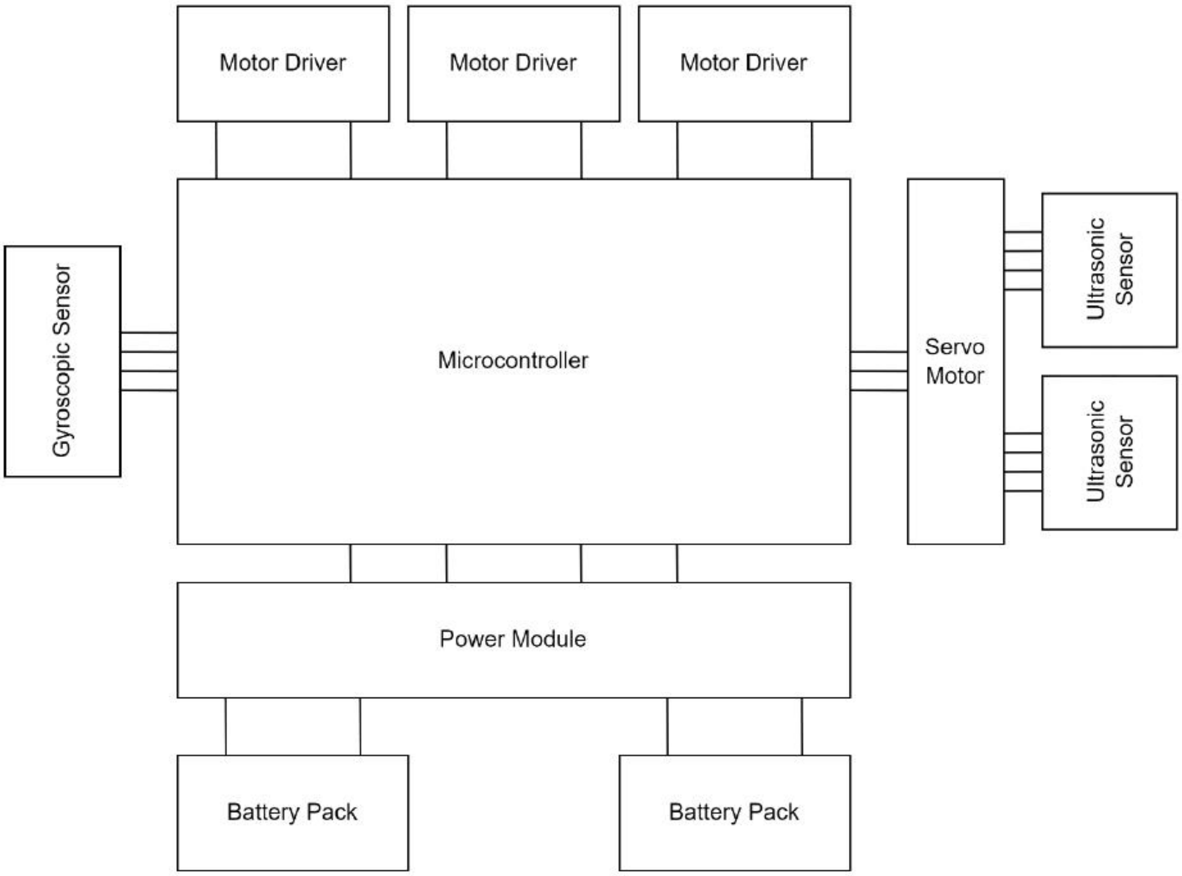


Fig . Circuit Connections



Block Diagram of the Solution

the robot also has a griper mechanism that is can be preprogrammed or controlled using the application

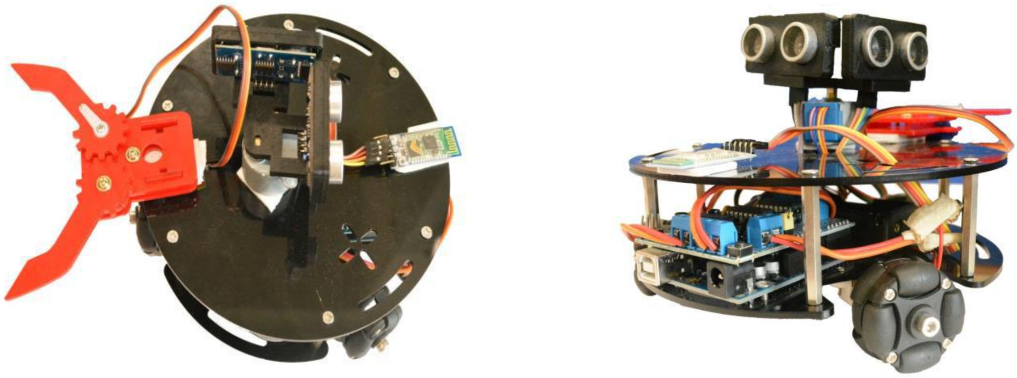


Fig. Actual scaled Prototype

Angle Mapping

The motor is fixed on the chassis and the motor orientation is such that they make angles of 0, 30, and 150 degrees respectively against the normal as stated in the below diagram therefore letting the three motors have the initial orientation of

Motor A = 0^o
Motor B = 30^o
Motor C = 150^o

The position of the bot can be calculated by using the distance formula, therefore, the initial position of the robot can be represented on the X, Y plane as

Coordinates for the Initial Position = (ipx,ipy)

and the final position can be given by

Coordinates for the Final Position = (px, py)

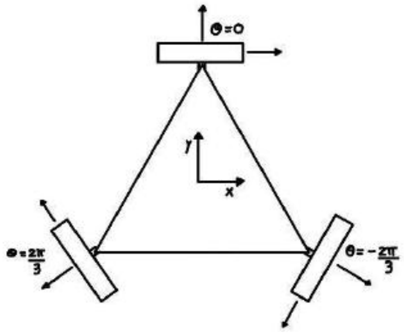
then the final orientation can be calculated by the below equation

$$A\theta = [(\left(\frac{py-ipy}{px-ipx}\right)) - 0°)]$$
$$B\theta = [(\left(\frac{py-ipy}{px-ipx}\right)) - 30°)]$$
$$C\theta = [(\left(\frac{py-ipy}{px-ipx}\right)) - 150°)]$$

Gyroscopic Deflection Angle = ϴ’. Inorder to position the robot in the given orientation the power required by the motor can be modulated by the given formula where the θ' is the gyro drift.

Power given to the motors

PA = $S\ cos\ cos\ (A\theta - \theta')$
PB = $S\ cos\ cos\ (B\theta - \theta')$
PC = $S\ cos\ cos\ (C\theta - \theta')$



RESULT

X, Y Input is given to the robot on the cartesian plane instead of using magnetic strips as used in conventional warehouse automation solutions. The motors in our solution run till the ultrasonic sensor reaches the final position provided by the user on the X-Y plane.

Out of a sample of 10 test runs, our robot reached the desired location 8 times, with an error of not more than 1cm the other 2 times.

DISCUSSION

The intention of this study is to develop an omnidirectional Warehouse Automation Solution which can reduce energy consumption and can be efficiently produced at low costs. The algorithm is very basic and effective and requires basic trigonometric calculations therefore using less processing power.

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