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A Review of AI for Urban Planning: Towards Building Sustainable Smart Cities

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ABSTRACT

Urban planning, in short, deals with solving the problems of the modern society. The problems are complementary to the growing population in today's society. The problems in society range from mundane tasks like ensuring sanitization in society to more technical tasks like managing infrastructures. The concept of smart cities, lately, has been a topic of great interest for social scientists, engineers, and everyone who wants to integrate technologies into their daily lives. AI and IoT have become an important part of our lives. Data has become ubiquitous with such smart devices that are connected to the internet. Such data can be used to make intelligent systems for smart cities. AI and IoT have promising effects on urban life. Artificial Intelligence is often considered to be the fourth industrial revolution because of its unprecedented potential to change everything. As AI progresses to improve day by day, it has blessed humans with everything from smart healthcare to secured smart cities. Everything has been changed by AI and IoT in smart cities. In this paper, the various use cases of AI and IoT for urban planning in order to build smart and sustainable cities are discussed. The proposed research work has reviewed various papers that could potentially be used in the development of smart cities.

Keywords— Artificial Intelligence, Internet of Things, Smart Cities, Sustainability, Urban Planning

1. INTRODUCTION

Urban Planning is the process of designing cities or broadly a living structure for human beings like towns or rural areas, in such a way that all the events that happen within this living structure are efficient and proper. Urban planning has been given many synonyms among which are town planning, regional planning, city planning. Urban planning in its core is about designing and developing structures in which human beings can live their day-to-day life effectively and without much hassle. It is a field that requires proper knowledge of various subjects which include political science, civil engineering, human geography, social sciences. Urban planning answers questions such as how people will live, how people will commute, how people will work, how garbages are disposed, how distribution channels function, how materials are transported, how sanitization will be implemented and many more such logistical questions that deal with people and their relation to a particular physical location, primarily the location where people's homes and workplace is situated [1].

Urban Planning is not a new concept. Kings and rulers of ancient cities implemented urban planning when building cities and settlements. However, their idea of urban planning was vastly different from the ideas of modern-day urban planning. Ancient urban planning mostly dealt with how homes, public buildings and streets were structured [2]. However, modern day urban planning deals with a much broader range of subjects such as transport optimization, traffic systems management, water leakage management, safety in streets and other things that are unique to the modern-day era [3].

Artificial intelligence is a field of computer science that deals with intelligent agents that are able to solve a task without the intervention of a human mind. It aims to create machines, robots or simply computational models that solve different problems in the world. The motivation for artificial intelligence comes from trying to mimic or replicate the functioning of the human mind [4]. The major subfield of Artificial Intelligence that is gaining wide recognition today is machine learning, because machine learning as a discipline finds many applications in various different subjects. The heart of machine learning is computational algorithms that are able to learn through data as well as improve over time. It does so using mathematical disciplines such as computational statistics and calculus as well as various other related subjects [5]. Artificial Intelligence and Machine learning finds many applications among a broad range of fields today. It has been estimated that around 47% of today's jobs will be replaced by artificially intelligent agents within a short span of 10 years. Artificial Intelligence and Machine learning finds applications in propelling the growth of businesses and since business is arguably the most important entity in today's economic world, it can be inferred that artificial intelligence has a huge impact in running the present-day world as well as building the future [6]. Presently, artificial intelligence and machine learning also finds application in medical diagnosis, easing the workload for medical practitioners [7].

Artificial intelligence is automating today's world and naturally it also finds applications in urban planning and urban design accelerating the development of smart cities. Since the 19th century Urban planning has been mainly concerned with improving the quality of people's lives based on the economical functioning of cities and on improving social equity. In the urban planning process, many functions are routine and automated with human labour but there also processes that need the intervention of a critical human mind. Within the short term, it has been predicted that many routine tasks will be overtaken by artificially intelligent systems whereas those tasks which require critical skills such as design will take more time to be replaced by automated systems [8]. Artificial Intelligence as is used today requires enormous amounts of data for its proper use. Since, today's modern cities are being digitized through the installation of CCTV cameras, sensors and large telecommunication networks it is possible to obtain data about how people in cities live, and how cities evolve over a certain period of time. It is possible to obtain data about land spaces, open spaces, buildings and such. Once this data is fed to the artificial intelligence system, primarily machine learning models, information about the urban fabric i.e., the logistics of the city comes to light and through proper reasoning and design urban planners are able to make use of it. Urban governance can also be implemented through these data obtained through various digital sources. Politicians can implement better policies that benefit the people living in urban areas because of information that comes out of an artificial intelligence model that processes the data. Artificial intelligence has also been used to make policies in urban planning that mitigates the effect of climate change and also policies that help in mitigating climate change, as in the modern world climate change is of paramount importance and designing cities that alleviates negative effects of climate change is quintessential. Even though AI influenced urban planning seems to be humanity's attempt at a futuristic world, it has its own flaws, like breach of privacy. Since large amounts of data need to be collected and stored for an AI model to work, the privacy of citizens living in smart cities is inherently disrupted. Since data has to be stored somewhere, there can be hackers trying to barge into centers and access unauthorized data. So there needs to be certain policies and techniques that safeguard the data of people [9].

2. RELEVANT WORKS

We have reviewed the latest artificial intelligence and machine learning techniques and its applications that could potentially be used in the development of smart cities. In particular we have reviewed Applications of AI in traffic system management, crime detection, air quality monitoring, efficient energy management and water leakage detection systems. There are a lot more applications that are quintessential in developing smart cities but these are the most important ones and hence we have reviewed recent popular research papers on them.

A. Traffic System Management

Yongchangma et al. [10] et al have proposed a framework for assessing the real time condition of a certain highway or a road. In their paper they use the concept of Vehicle Infrastructure Integration (VII). In this concept vehicles have computational units as well as infrastructure in the road have computational units, and these units are able to communicate with one another along a communication network. The computational unit and sensors in the vehicles are able to detect the speed profiles, wheel turning as well lane changing behavior of the vehicles. With all these data, it is important to classify them into classes of information so as to know the condition of the traffic. Yongchangma et al used support vector machines to classify the data into 3 classes of information namely, normal, passed by a possible incident or stooped in a queue. This classification was done for each vehicle infrastructure integration enabled vehicle. They compared support vector machines with artificial neural networks for the classification and found that the support vector machines performed better given the same training set and test set. The false alarm rate detected by their system was also considerably low. Their system was also further able to classify incidents blocking one lane, two lanes and three lanes. It was found that the SVM performed much slower when the density of vehicle infrastructure enabled vehicles increased, however not by much. The experiment done by them was performed via a traffic simulation software and not in a real road network. So trying to extrapolate this research into a real road network might not turn out to be as accurate or efficient. However, this paper shows that with the right technology and the correct use of machine learning models it is possible to have a real time system that is able to accurately predict traffic configurations.

Nallapermua et al. [11] have proposed a system names STMP (Smart Traffic management platform) that is able to harness the power of big data and artificial intelligence algorithms. The system makes use of sensor networks in roadways, Internet of Things (IoT) as well as social media data to make predictions on traffic flow as well as give solutions to traffic management problems. Their system primarily does the following things:

a. Detect concept drifts such as peak hours/non peak hours as well as incidents in roadways such as accidents. This all happens real time. This system is implemented through an online incremental machine learning algorithm based on Incremental Knowledge Acquisition and Self Learning (IKASL) algorithm.
b. Determine the sentiment and emotion of vehicle users using social media data in a non-recurrent traffic event such as an accident.
c. Use real time traffic data to provide optimal traffic control strategies using deep reinforcement learning.
d. Predict traffic flow and make estimates on impact propagation using deep neural networks.

Their system was run on a smart sensor network traffic data generated by hundreds of thousands of vehicles on the arterial road network in a state in Australia. Their system provided very good results and was also implementable in the real world. The high-level overview of the architecture is as shown in fig. 1.

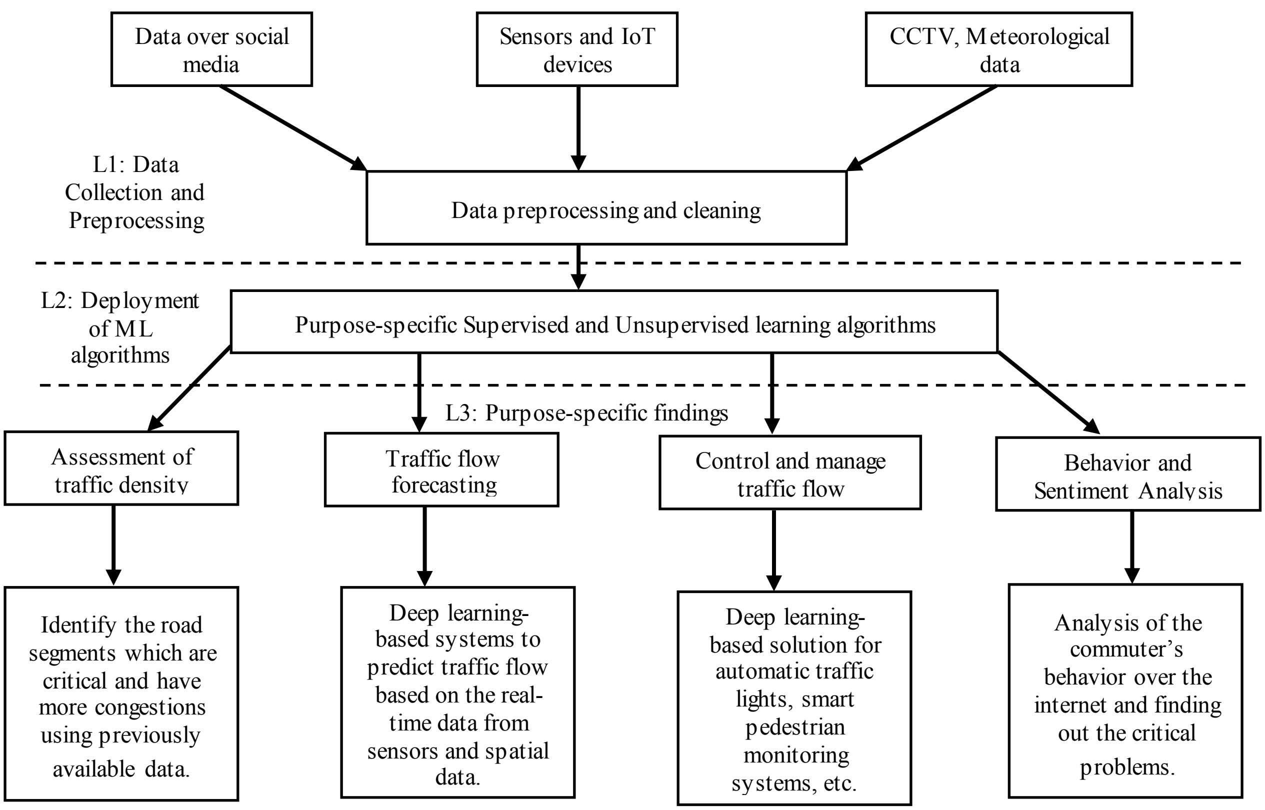

Fig. 1. Smart Traffic Management Architecture

Wang et al. [12] have proposed a system which can detect traffic jams in a freeway using camera video footage and images. This is an essential step towards building a smart city because ideally in a smart city there should be a system that detects and resolves traffic jams in the city. Their system deals with the detection part only and not the resolution part. They use CNN architecture for this system. The various different CNN architectures they use are VCGNET, AlexNET specifically they have tested and compared AlexNet + SVM, Transfer Learning from AlexNet, Transfer learning from VCGNet and VCGNet + SVM architecture. The dataset they used consisted of 30,000 traffic congestion images and 20,000 non congestion images and they obtained the dataset from a surveillance system used in Shaanxi Province Traffic Management Bureau. The accuracy they obtained was 90% using the transfer learning from AlexNet architecture.

B. Crime Detection

It is of paramount importance that surveillance systems in smart cities are able to automatically detect unusual activities such as crimes, robberies, shooting and further alarm the concerned authorities. Much research has been done using artificial intelligence and machine learning techniques to solve this particular problem of crime detection or largely anomaly detection in surveillance systems. Having such automatic systems would greatly reduce human intervention and the need for 24/7 security. Many researchers have worked on this problem and produced models that are able to give high accuracy on certain datasets, however employing these models in the real world do not yet give the same accuracy as they do on simple datasets [13]. Employing these techniques would harness safer streets for women, decrease crime and theft considerably and improve the well-being of the general people.

Ullah et al. [14] have proposed a deep learning model that is able to detect violence in surveillance systems. Their system consists of the Convolutional neural network architecture and SoftMax layer for output classification as shown in fig. 2. Their system primarily consists of 4 parts. In the first part a CNN model was used for object detection, mainly human detection. If a human was detected a stream of 16 frames was passed onto a 3D CNN that extracted features from the sequence of frames. These features were further passed onto a SoftMax layer for classification. If the SoftMax layer predicted that violence was detected their system alerted a nearby police station and the concerned authorities. They tested their model on three different popular datasets for violence detection and they were hockey fight dataset, violent crowd dataset, and violence in movies dataset. When their model was trained on the violent crowd dataset, testing it against the violent crowd dataset gave an accuracy of 98%, whereas when they tested this model on violence in movies dataset and hockey fight dataset it gave accuracies of 65% and 47% respectively. When their model was trained on the violence in movies dataset, testing it against the violence in movies dataset gave an accuracy of 99.9%, whereas when they tested this model on violent crowd dataset and hockey fight dataset it gave accuracies of 54% and 63% respectively. When their model was trained on the hockey dataset, testing it against the violent crowd dataset gave an accuracy of 96, whereas when they tested this model on violent crowd dataset and violence in movies dataset it gave accuracies of 52% and 49% respectively. Their model gave exceptional accuracy for a particular dataset but it was not able to generalize well into other datasets. For a violence detection surveillance system to work in the real world, it has to generalize into different datasets as the surveillance environment may vary.

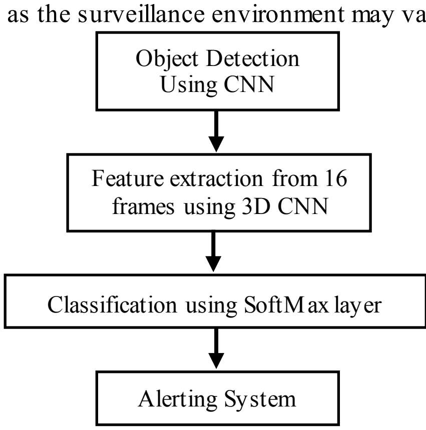

Fig. 2. Model of ullah et al. [14] for violence detection in surveillance systems

Bappee et al. [15] have proposed a way to relate geospatial features to crime. They used features such as the coordinates, postal code, hubs like cafes near the area as well as measures such as distance nearest to the hotpoint. A hot point is referred to as an area where crime happens. Their data consisted of 4 labels namely, alcohol related fights and accidents, assault, property damage and motor vehicle related accidents. The classifiers they used were Logistic regression classifier, support vector machines and random forest classifier. Their research is very important in the context of urban planning because it shows some sort of relation between geospatial features and crimes. Using this information, urban planners can design cities that are less prone to crime.

C. Air quality monitoring

It is important for smart cities to have automatic air quality monitoring systems that are able to detect the quality of the surrounding air and alarm the concerned authorities in case of any anomaly.

Wu et al. [16] have proposed a system that can detect the air quality using computational lens free microscopy and machine learning algorithms. Their system is named C-Air and it is also combined with a smartphone application that can control various parameters as well as display the results. It consists of a device that is able to take microscopic images of the particles in the air and the machine learning model is responsible for predicting what particles are present in the image and the size of the particles. They used a custom-designed machine learning algorithm. The accuracy of the model for predicting the size was found to be around 93%. They did some testing with this system and found that the air quality increased as the distance from the airport increased and hence it is known that the air quality near an airport is much worse than average.

Saad et al. [17] have proposed a system that is able to detect indoor air quality using sensors and supervised machine learning algorithms as shown in fig. 3. In their

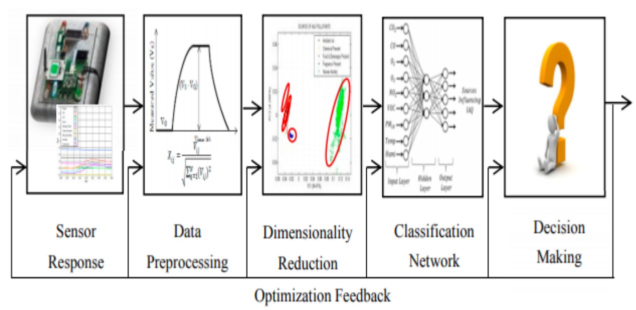

Fig. 3. Indoor air quality detection system as proposed by saad et al. [17]

experiment they used a couple of sensors that were able to detect 9 different parameters. The parameters were temperature, humidity, ozone(O3), oxygen(O2), volatile organic compounds (VOC), carbon monoxide (CO), nitrogen oxide (NO2), carbon dioxide (CO2) and particulate matter (PM10). Their system was able to classify 5 different output classes namely, presence of fragrance, presence of food and beverages, ambient air, combustion activity and presence of chemicals. They collected the data themselves and didn't use any popular dataset. They tested their self-collected data with a lot of traditional machine learning models and found that 3 of the models gave an accuracy of up to 100%. The three models were multi-layer perceptron, linear discriminant analysis and k nearest neighbors. When there was a presence of more output classes indoors at the same time their model was unable to correctly classify and gave the output as unknown. Their research is very important in the context of building smart cities because ideally all homes would have an automatic air quality detection system and in the case of some sort of an anomaly like a gas leakage the concerned authorities or the homeowner would be informed.

D. Efficient Energy Management

It is of paramount importance that energy usage is optimized and properly utilized in smart cities. Using energy management schemes, it is possible to distribute energy to various locations in a smart city such that there is no energy loss and energy is properly distributed according to the need of the area. Energy Management is not just concerned with the consumer of energy but also with the supplier of energy. In today's world, there are many sources of energy such as renewable sources and non-renewable sources, so it would be important in smart cities to be able to distribute the energy to households and buildings efficiently. Energy management schemes also come into play when the amount of energy that can be distributed is limited. The energy that we are talking about here is largely electrical energy.

One of the key parts in an electrical management system is electrical load forecasting, that is to be able to forecast how much energy a particular area would use at a particular point of time. This is important so that more electrical energy than needed is not sent to this area, thus effectively managing the distribution of electricity. Khan et al. [18] have proposed a machine learning model that predicts electrical load in time series data based on machine learning models. The dataset they have used is South Korea's hourly energy consumption. The data set contained huge gaps, around 21%. They use several predictive machine learning that predict the values at the gaps to fill in the gaps. The classifier they used was a hybrid classifier that consisted of three machine learning models namely, XGBoost, CatBoost and random forests. They compared their hybrid model with several existing machine learning models and found that their hybrid model gave the best results. In time series forecasting the measure that we use to know the effectiveness of the model is regression score. It was found that the regression score of XGBoost, CatBoost and random forests were 0.8195, 0.8294, 0.7996. The hybrid model proposed by Khan et al had a regression score of 0.9212, thus outperforming the traditional machine learning models.

Kim et al. [19] conducted a research in which they effectively predicted the energy consumption of a particular household based on the features of the house which include number of exterior walls in that house, area of the house, number of years occupied, numbers of household members, occupation of the household members among other features. They firstly divided the data according to the period of the year. The periods were fall, summer, winter and autumn. Among the large feature set they performed regression analysis for each period and selected the input features. The classification model that they used was the artificial neural network model. They used the Household Energy Standing Survey dataset. Their research found that inspiring the building direction was the most influential element in predicting energy consumption. In summer it was the heating method, colling method and the area of the household. IN fall it was the housing area, housing type and occupation of the household members and in winter it was building direction, housing area and occupation of the household members.

E. Water Leakage Detection

Water is one of the most essential elements to life. Smart and efficient distribution of water is a must in cities. It has been known that the water pipeline leakage rate is 22% in Asia [20]. Hence it is important to build systems that are able to detect water leakage and stop them. An automatic water leakage detection, localization and resolution system is very important in the development of truly smart cities. Much research has been done on this topic particularly in water leakage detection and localization systems.

Kang et al. [21] have proposed an artificial intelligence system that is able to detect water leakage in water distribution systems. Their system is also able to localize the area of the water distribution system where the leakage is happening. In their system a leakage monitoring system was installed in a water distribution system. The leakage monitoring system and sensors that captured noise data and other data in the form of signals. The machine learning model they used was an ensemble of 1D CNN and SVM. The localization technique they used was based on graph theory and the water pipeline system was represented as a graph. It was found that their system correctly identified water leakage up to an accuracy of 99.3% and gave a localization error of less than 3m. Using their system, it is possible to build real world water leakage detection and localization systems. Their work can undoubtedly be used in building water pipeline distribution systems in smart cities.

3. DISCUSSION AND FURTHER APPLICATIONS

Table I mentions some of the works that have been done in the field of urban planning using artificial intelligence. There are many other applications of artificial intelligence on the development of smart cities and in modern urban planning. It is important for urban planners to know the layout of cities. Traditionally, Human labor was used to find the specific layout of cities, but with the advancement of technology it is possible to analyze the layout of cities using geospatial imagery [22]. Using satellite imagery, computational techniques are automatically able to detect and identify different types of objects present in the image, thus making analysis of infrastructure in cities a million times easier and faster, and subsequently making the urban design and planning procedure much quicker and easier.

In smart cities, theoretically every single aspect would be automated. Recent advancement in the field of Artificial intelligence has made it possible to automate the field of road repairing as well. From the detection phase of road cracks and anomalies to the repairing process can be automated. Kumar et al. [24] have done a study on detection of cracks from geospatial imagery of roads. Their model uses Convolutional neural networks, a deep learning framework to solve the problem of crack detection. Principal Component Analysis is also incorporated in their work. We can use their work for building an automatic road repairing system. Their work can be used in the detection phase of road cracks, and further systems can be created that will alert the concerned authorities on the matter. The alerting process can also be optimized wherein cracks in important roads are detected and notified first. Many problems can be solved with AI, IoT and automation. Problems that occur accidentally and are usually difficult to handle like tackling pandemic can also be solved with these technologies [23].

It is important for smart cities to ponder upon and implement the concept of sustainability as well. Due to the recent environmental crisis, it has become increasingly important to develop the modern world in a sustainable manner. Urban planning should incorporate sustainable development into its philosophy for a better and healthier world for our children. Artificial Intelligence also sees use cases in the area of sustainable development.

4. CONCLUSION AND FUTURE SCOPE

In this paper, the various frameworks and technologies for smart cities are discussed. The concept of smart cities is ever changing. With engineering and social sciences leaping towards perfection every day, there is always a scope for improvement in existing infrastructures and technology. The research in artificial intelligence is booming which has affected every mundane and advanced thing. It has become self-evident that the integration of IoT and AI in our day-to-day activities has made our lives easier. The complex barriers for smart cities are broken down by AI and IoT. In this paper we have reviewed various recent studies done on artificial intelligence that could potentially be used in the making of smart cities. From various successful use cases of AI and IoT discussed above, it is unanimous that intelligent systems can solve the existing problems in more convenient ways. The upcoming innovation and technologies are certain to change our lives by meeting the concept of smart cities. From smart homes to safe streets for women, AI and IoT has changed each and every prospects of a society and will continue to do so with booming innovations in engineering and technology. In the future, the technology might be able to solve the problems that are even beyond the capacity of engineering and technology today to make the world a better place to live.

TABLE I. RECENT WORKS IN THE FIELD OF URBAN PLANNING AND SMART CITIES

Name of Author	Year of Publication	Methods used	Use case
Yongchcangma et al. [10]	2009	Vehicle infrastructure integration + support vector machines	Traffic system management
Nallaperuma et al. [11]	2019	Incremental machine learning algorithm, deep neural network and deep reinforcement learning	Traffic system management
Wang et al. [12]	2018	CNN	Traffic system management
Ullah et al. [14]	2019	2D CNN + 3D CNN + SoftMax	Crime Detection
Bappee et al. [15]	2018	Logistic regression classifier, support vector machines and random forest classifier	Crime detection
Wu et al. [16]	2017	Custom designed machine learning algorithm	Air quality monitoring
Saad et al. [17]	2017	Multi-layer perceptron, Linear discriminant analysis and K nearest neighbours	Air quality monitoring
Khan et al. [18]	2020	Ensemble of XGBoost, CatBoost and random forest	Efficient Energy management
Kim et al. [19]	2019	Regression analysis + Artificial Neural Networks	Efficient energy management
Kang et al. [21]	2017	1D CNN + SVM and graph theory	Water leakage detection

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