Research on Factors Affecting the Number of Roadside Parking Based on Empirical Mode Decomposition

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Abstract

The number of on-street parking is affected by many factors such as holidays and seasonality, so it has significant nonlinearity and non-stationarity.Different from previous studies, this paper proposes the application of empirical mode decomposition(EMD) to analyze the number sequence of roadside parking.Taking the number of roadside parking in Xi'an for one year as an example, it is decomposed according to the intrinsic mode function and residual term obtained after decomposition. Finally, the influence of holidays at high frequency and the seasonal influence at low frequency are obtained. It has important guiding significance for the planning of roadside parking berths.

Keywords

Empirical mode decomposition, number of roadside parking, time series analysis.

1. Introduction

With the sustained and steady growth of China's economy and the rapid development of the automobile industry, the number of urban motor vehicles has increased sharply, resulting in worse and worse traffic conditions in the city, and the difficulty of parking due to insufficient parking facilities in large and medium-sized cities in China. Increasingly serious, the contradiction between parking supply and demand is prominent, which seriously affects the normal traffic order of the road.The problem of “difficult parking” has become a major problem that restricts urban development, and has attracted the attention of relevant state departments and local government authorities.In 2010, the Ministry of Housing and Urban-Rural Development and the Ministry of Public Security and the National Development and Reform Commission issued the “Guiding Opinions on Strengthening the Planning, Construction and Management of Urban Parking Facilities”, which put forward general requirements and deployment for urban parking development.In 2015, in order to implement the State Council's deployment, the Ministry of Housing and Urban-Rural Development has successively issued the “Guidelines for Urban Parking Facilities Planning”, “Guidelines for the Construction of Urban Parking Facilities” and “Notice on Strengthening the Management of Urban Parking Facilities”, from Planning, Construction and Management. In terms of strengthening the guidance of the parking industry.

At present, the research on roadside parking at home and abroad mainly focuses on the impact of roadside parking management and roadside parking on road traffic capacity.In terms of on-street parking management, domestic scholar Liren Peng, Futian Ren et al. believe that roadside parking planning in different cities and locations needs to consider factors such as road traffic conditions, off-street parking facilities, traffic management levels, etc., and proposes systematicity in planning. , coordination, dynamics, and principles of operability[1].Yaguo Xu proposed the conditions and methods of roadside parking to regulate the setting and management of on-street parking, improve traffic order, and alleviate the traffic congestion of urban roads[2].Foreign scholar D.Coombe et al. proposed a parking control strategy to reduce traffic conditions in urban congested areas and established an analytical model to evaluate the impact of parking control strategies[3]..Debasish Das and Mokaddes Ali Ahmed evaluated the roadside parking service level from three aspects: parking characteristics, safety characteristics and design characteristics. The AHP analytic hierarchy process was used to determine the weights, and the cluster analysis method was used to standardize the variables. Select cases for verification analysis and make reasonable comments[4].

In terms of the impact of on-street parking on road capacity, domestic scholar Yaqin He et al., based on the analysis of the impact of on-street parking on road traffic flow, established a road capacity model based on parallel roadside parking, and proposed Suggestions on measures to improve traffic capacity when parking on the roadside[5].Changqiao Shao et al., by analyzing the survey data, consider the influence of roadside parking on traffic capacity from three aspects: lane width, lateral clearance and vehicle intake and travel frequency, and obtain the relationship model between roadside parking and road capacity[6].Based on the results of parallel and oblique roadside parking surveys, Yousif discussed the traffic conditions of roadside parking sections by analyzing the parking time and receiving gaps. The results show that the design of the parking space layout on the road will drive the driver. And the driving behavior has a great impact, and finally proposed the parking space design according to the actual situation in the local area[7].Y.Cao,ZZYang,ZYZuo established a description road by considering the traffic flow, vehicle speed, traffic conflict and other parameters, taking into account the traffic safety of roadside parking for motor vehicles and non-motor vehicles and the impact on pedestrian crossing. The model of the capacity of the parking road, the research results show that the effective width of the lane has the greatest impact on road capacity[8].

At home and abroad, there is a lack of research on the factors affecting the number of on-street parking. Therefore, this paper reveals the intrinsic characteristics of the data sequence through empirical mode decomposition from the number of roadside parking itself, and better influences the roadside. The number of parking factors provides a reference for subsequent research.

2. Basic theory of empirical mode decomposition

2.1 The basic concept of empirical mode decomposition

Empirical Mode Decomposition (EMD) is a new adaptive signal time-frequency processing method proposed by N.E.Huang in 1998 by NASA and others[9]. Compared with the traditional time series decomposition method, EMD can overcome some inherent constraints, based only on the time scale characteristics of the data itself. It is used to decompose the original signal, so it is especially suitable for the analysis processing of nonlinear non-stationary signals.

Time-frequency analysis based on empirical mode decomposition mainly involves two different steps.First, by performing empirical mode decomposition on the original time series, the original signal is decomposed into the sum of different intrinsic mode functions; Then, by performing Hilbert transformation on each intrinsic mode function, the instantaneous frequency of each intrinsic mode function is obtained.Therefore, this involves two concepts: instantaneous frequency and intrinsic mode function.

1.Instantaneous frequency

Instantaneous frequency refers to the frequency of the signal as a function of time.In the general sense, frequency refers to a sine or cosine function with a constant amplitude throughout the length of the data.If the length is less than one wavelength, the definition of the frequency cannot be calculated.Therefore, in order to be able to represent the local features of the signal, the concept of instantaneous frequency is proposed.The instantaneous frequency can be thought of as a sine wave local optimum approximation of the analyzed signal frequency value.Since the instantaneous frequency is a function of time t, that is, only one frequency at each time point uniquely corresponds to it, it can only be used to represent a single component signal.In order to obtain a single component signal of a multi-component combined signal, it is necessary to use the empirical mode decomposition algorithm introduced in this chapter to decompose the signal to obtain a set of single-packet signals, that is, the intrinsic mode function.

2.Intrinsic mode function

According to the definition of the instantaneous frequency above, if the instantaneous frequency is to be meaningful, then the necessary condition is that the function is symmetrical, the local mean is zero, and the number of zero crossings and extreme points are equal.Therefore, in order to decompose the composite signal into several single-component combinations, Huang et al. proposed a method of empirical mode decomposition.The EMD method is to linearize and smooth the nonlinear non-stationary signal. By decomposing the fluctuations on the scales at different times, the trend component is finally obtained.In the process of decomposition, the characteristics of the data itself are preserved; those separated wave components are called Intrinsic Mode Function(IMF).The IMF characterizes the wave characteristics of different feature scales. The original data sequence decomposes the different IMF components and the remaining components are called trend components, which are used to characterize the long-term trend of the time series.

For EMD decomposition, the most important thing is the extraction of the IMF component.For each of the extracted IMF components, it has the following two characteristics:

(1). From the perspective of the entire time range of the function, the number of local extreme points and zero crossings must be equal, or at most one difference;

(2). From the characteristics of each local feature.At any point in time, the average of the envelope of the local maximum (upper envelope) and the envelope of the local minimum (lower envelope) must be zero, ie the signal must be sufficient to satisfy the local symmetry about the time axis.

2.2 The basic principle and algorithm flow of empirical mode decomposition

In practical applications, most of the original signals we are exposed to are multi-component signals, and the characteristics of these original signals are difficult to analyze to some extent, because the single-component signal has only one frequency at each moment. Therefore, its characteristics are relatively well described.Therefore, EMD is to decompose those complex original signals to obtain a single-component intrinsic mode function that is easy to analyze.

Before EMD decomposition, we need to assume:

1. The data sequence of the original sequence contains at least two extreme values, one maximum value and one minimum value;

2. The local time domain characteristic of the data sequence of the original signal is uniquely determined by the time scale between the extreme points;

3. If the original sequence has no extreme points but has an inflection point, then the extreme points can be obtained by differentially dividing the data, and then the decomposition result is obtained by integration.

The basic idea of EMD decomposition can be seen as a screening process.First, it is necessary to find the local maximum value and the local minimum value point of the original signal; then, the found extreme point is processed to obtain the upper envelope and the lower envelope of the signal, thereby obtaining the upper envelope and The mean value of the lower envelope is then filtered by the filtering algorithm to filter the original signal into several intrinsic mode functions and one residual term.There is no direct relationship between the intrinsic mode functions obtained by EMD decomposition, and the frequency of the decomposed IMF function is gradually reduced.The specific implementation algorithm description is as follows[10]:

Find the original sequence $\mathrm{x(t)}$ all maxima and minima;

Use the cubic spline function to fit the extreme points in 1 respectively to generate the upper envelope$e_{max}(t)$And lower envelope$e_{min}(t)$;

Calculate the arithmetic mean of the envelope and the lower envelope at any time$m_1(\mathrm{t})$:

$$m_1(\mathrm{t}) = \frac{e_{max}(t) + e_{min}(t)}{2}$$

The component of the average envelope is removed from the original sequence x(t), resulting in a new data sequence with the low frequency signal removed:

$$h_1(\mathrm{t}) = \mathrm{x}(\mathrm{t}) - m_1(\mathrm{t})$$

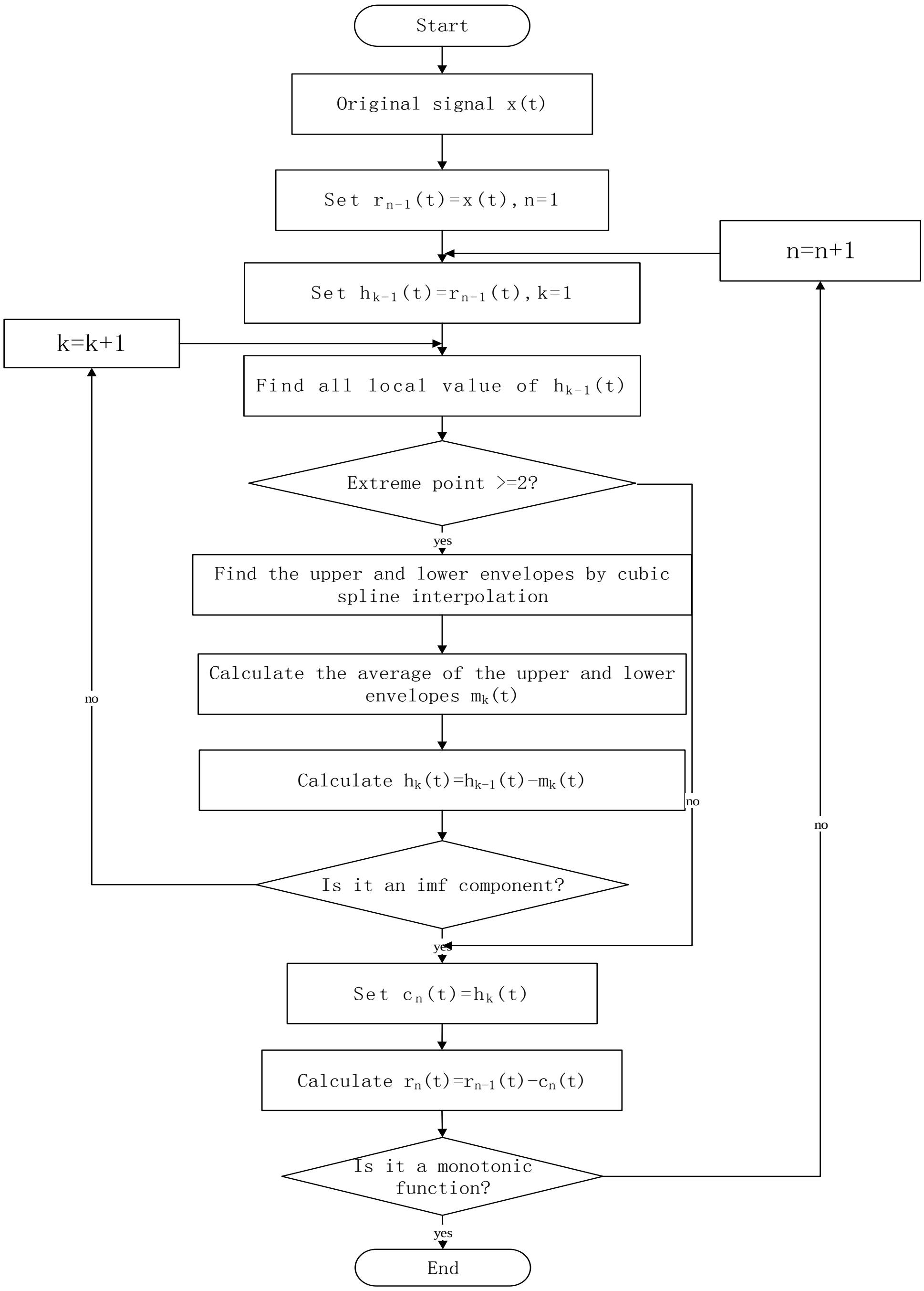

Figure 1. EMD decomposition algorithm flow chart

Examination $h_1(\mathrm{t})$ whether the conditions of the IMF are met: If not, take this as a new sequence and repeat the above steps k times until $h_1(\mathrm{t})$ Meet the imf condition.Then define $c_1(t) = h_1(\mathrm{t})$Then$c_1(t)$It is the first imf fluctuation component decomposed by the original sequence.

The first IMF component is removed in the original sequence to obtain the first differential sequence with the high frequency component removed:

$$r_1(t) = x(t) - c_1(t)$$

Repeat$r_1(t)$ as a new sequence, repeat the above steps to get the second IMF component of the original sequence.$c_2(t)$And remaining items$r_2(t)$.

Repeat all the above steps n times until the last remaining component$r_n(t)$can not continue to break down.This will give you the individual components of the original sequence at different time scales.$c_i(t)$(i=1, 2,...,n) and the residual term representing the trend term$r_n(t)$.

The final original sequence can be expressed as:

$$\mathrm{x(t)} = \sum_{i-1}^{N} d_i(t) + r_n(t)$$

According to the above description, the flow chart of the EMD algorithm can be finally obtained as shown in the following figure.

Where N is the number of IMFs and r(t) is the last residual sequence.$d_i(t)$For the ith IMF.The frequency of the IMF decomposed by the EMD method is gradually reduced according to the order in which it is decomposed, and each IMF contains the variation characteristics of the original sequence on different time scales.

3. Empirical mode decomposition-taking the roadside parking in Xi'an as an example

3.1 Processing of raw data

This article uses data collected by Xi'an Parking Management Company, which includes the number of on-street parking for the full year of 2016.The data is processed using the SAS software to obtain the number of parking spaces per day for all roadside parking berths. Some of the data are shown in Table 1.According to the data obtained, the missing data appeared in some dates in October and November. Therefore, the missing values need to be processed for subsequent analysis.

Table 1. Statistics of daily parking volume in 2016 (partial)

date	Number of parking	date	Number of parking		date	Number of parking	date	Number of parking	
01-01	47758	02-01	58950		10-01	52266	11-01	67069	
01-02	49046	02-02	62563		10-02	47791	11-02	67856	
01-03	49229	02-03	60851		10-03	46139	11-03	68281	
01-04	57430	02-04	55559		10-04	47235	11-04	67853	
01-05	58403	02-05	44832		10-05	39363	11-05	65456	
01-06	59290	02-06	22984	…	10-06	48256	11-06	56165	…
01-07	59397	02-07	120	…	10-07	51758	11-07	62354	…
01-08	60002	02-08	113		10-08	66636	11-08	68803	
01-09	55311	02-09	117		10-09	57616	11-09	67897	
01-10	52828	02-10	162		10-10	67702	11-10	69353	
01-11	58016	02-11	229		10-11	68812	11-11	69832	
01-12	49289	02-12	224		10-12	64979	11-12	65158	
01-13	60517	02-13	382		10-13	69079	11-13	61040	

01-14	60513	02-14	27494		10-14	67391	11-14	67530	
01-15	60196	02-15	42399		10-15	66404	11-15	63990	
01-16	56939	02-16	49543		10-16	61256	11-16	63524	
01-17	53973	02-17	55766		10-17	68664	11-17	63585	
01-18	60591	02-18	57962		10-18	69001	11-18	64271	
01-19	58667	02-19	59405		10-19	69135	11-19	65917	
01-20	57533	02-20	58185		10-20	68055	11-20	61809	
01-21	61404	02-21	53205		10-21	62592	11-21	57644	
01-22	50923	02-22	65083		10-22	48431	11-22	23762	
01-23	55539	02-23	57426		10-23	43658	11-23	50628	
01-24	52032	02-24	61887		10-24	-	11-24	62591	
01-25	59103	02-25	61825		10-25	-	11-25	67948	
01-26	62426	02-26	62672		10-26	-	11-26	37295	
01-27	64228	02-27	61153		10-27	-	11-27	-	
01-28	64297	02-28	59311		10-28	-	11-28	-	
01-29	65348	02-29	66055		10-29	-	11-29	-	
01-30	58266				10-30	-	11-30	-	
01-31	27386				10-31	-			

Since the missing data has a significant impact on subsequent analysis, it is not easy to delete and other processing methods. Therefore, the data of the parking number of the parking berths obtained is imported into the SPSS, and the SPSS software is used to adopt the linear interpolation method. The missing values are processed to supplement.The processed data is shown in Table 2.

Table 2. Data after missing value processing

date	Number of parking
10-24	45330
10-25	47002
10-26	50347
10-27	52019
10-28	53691
10-29	57036
10-30	60380
10-31	63725
11-27	43607

11-28	49919
11-29	56230
11-30	62542

3.2 Matlab programming to achieve EMD decomposition

The EMD decomposition is realized by Matlab platform programming, and finally the 5 IMF components and residuals of the original sequence are obtained. As shown in Fig. 2, the ECG is the original sequence, and imf1, imf2, imf3, imf4, and imf5 are the decomposed 5 An intrinsic mode function, res. is the residual.As can be seen from the figure, the fluctuation frequency of each IMF component gradually decreases, and the amplitude gradually becomes larger.

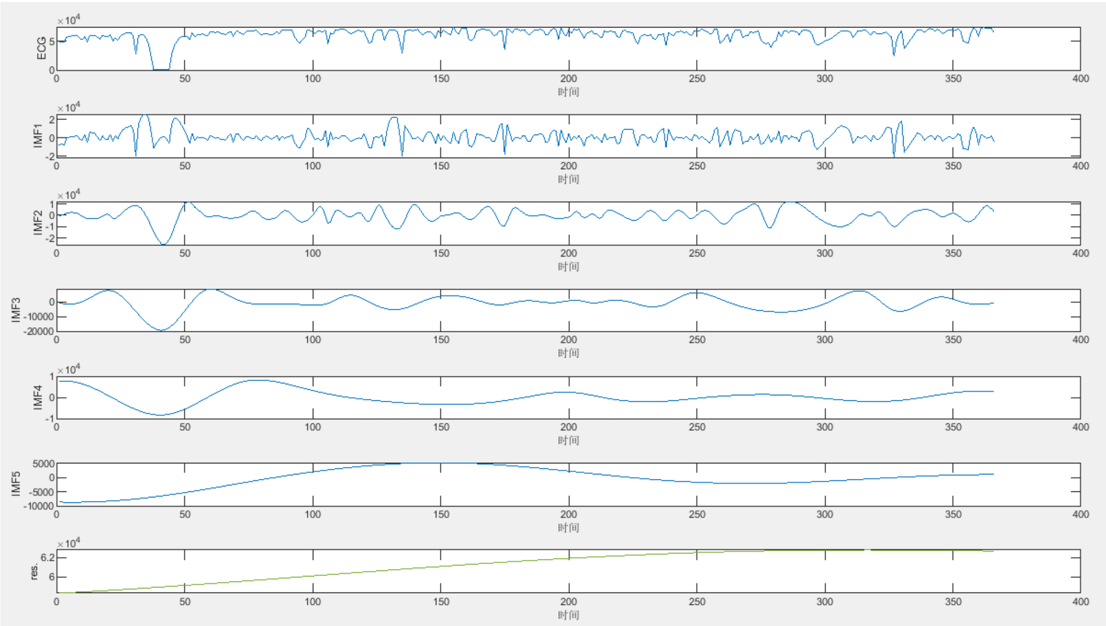

Figure 2. Schematic diagram of each IMF component of the number of roadside parking

Table 3. Average period statistics of each component

	Average period (days)
IMF1	4
IMF2	13
IMF3	33
IMF4	73
IMF5	183
Residual item	366

Table 3 shows the average period of each IMF component, and the average period is obtained by dividing the sample size by the number of maxima of each IMF component[11].

From the statistical calculation results, the average period of imf1 is the shortest, about four days; the average period of imf2 is about two weeks; the average period of imf3 is about one month; the average period of imf4 is about one quarter (three months); The average period of imf5 is the longest, about six months.They represent the variation of the original sequence on different time scales.

According to the decomposition results, from the short period of imf1, the number of parking per day has a certain volatility as a whole, and there are obvious fluctuations in about 40 days. The reason is that these days are in the Spring Festival holidays, and the number of parking during the holidays. There is a significant reduction, and after the holidays, the number of parking has increased significantly, so the volatility is more obvious during this period of time.The fluctuations that occur at other time points may also be due to the existence of various small holidays, such as May Day Labor Day, National Day and other holidays, resulting in greater volatility before and after.

The average period of imf2 is about two weeks. From this decomposition result, the volatility of parking quantity is not so obvious compared with the imf1 decomposition. The most obvious fluctuation is also in the fourth week, which is the Spring Festival holiday. The arrival of the outgoing staff returned to their hometown to go to the festival, which will result in a decrease in traffic, which in turn led to a sharp decline in the number of on-street parking; while other small holidays have no drastic changes like the Spring Festival, so its volatility is not so obvious.

The average period of imf3 is about one month. It can be seen that there are obvious troughs and peaks and valleys in the second month. This is because at the beginning of the month, it is in the Spring Festival holiday, so the number of parking has reached the lowest state, and at the end of the month. It coincides with the school day, so it reached the highest point of parking during this time; during other months, such as in April, May, June and October, because of the existence of small holidays, The number of parking has a certain growth trend during the month, and the number of parking has declined significantly during September, probably because of the Mid-Autumn Festival in September, and for these traditional Chinese festivals, such as the Spring Festival and Mid-Autumn Festival Everyone is more inclined to family reunion, so the number of parking will be reduced during this time.But the number of parking lots in these months has not been as great as the fluctuations in February.

The average period of imf4 is about one quarter. From the perspective of the quarter, the volatility of the number of parking is relatively flat. The biggest fluctuation is in the first quarter, because the number of parking has dropped sharply in the first quarter. The Spring Festival holiday, the subsequent quarters are relatively flat, so from the entire quarter, the impact of other holidays on the number of parking is not as big as the Spring Festival holiday.

The average period of imf5 is about six months. From the perspective of this decomposition, the number of parking in the first half of the year is highly volatile, and the fluctuation in the second half is small. This is also the factor affecting the Chinese New Year holidays in the first half of the year.In addition, from the decomposition results, there are also certain seasonal factors. For spring and autumn, the number of parking is relatively small, while in summer and winter, the number of parking is relatively large, indicating that when the weather is mild and pleasant, people I prefer not to drive by car, but when the weather is hot or cold, people are more willing to choose to drive. It is obvious that seasonal factors have a certain impact on roadside parking. The situation is different.

The residual term represents the long-term trend of the original sequence. In the long run, although the number of parking has fluctuated to varying degrees, it is still in a growing trend as a whole.This implies that with the growth of China's economy and the improvement of national living standards, the number of cars is also growing, so the demand for parking lots will continue to increase.Therefore, the government should take some measures in a timely manner to protect everyone's travel and parking needs in different time periods and sub-regions, and to improve everyone's life satisfaction.

4. Conclusion

According to the above analysis, due to the existence of some holidays, the number of roadside parking will be obviously fluctuating. After the decomposition of EMD, it is easier for us to analyze it. From the perspective of short cycle, the impact of holidays on roadside parking Larger, trend volatility is stronger; from a longer cycle, due to the increase in cycle time, the impact of holidays tends to fade, resulting in more volatility, but from different seasonal perspectives, different seasons Parking conditions vary, so holidays and seasonal changes can have a certain impact on on-street parking.

By EMD decomposition of the number of on-street parking, the factors affecting the number of on-street parking are seen from different angles, and the follow-up managers provide reasonable ideas for the planning of on-street parking from different angles to better meet people's travel needs.

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