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FOURIER SERIES NONPARAMETRIC REGRESSION FOR THE MODELIZING OF THE TIDAL

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Abstract

The method of statistic used to estimate the estimation of sea water level is by nonparametric regression approaching of Fourier series. The rob flood caused by sea level rise in Semarang becomes a dissolved problem until today This results the need of modeling to predict and know how high sea level is. The fourier series have fluctuative data pattern because of its periodic character. This makes Fourier series as the appropriate approaching to modelize the sea tidal. Before modelizing the sea tidal with Fourier series approaching, It is previously necessary to find the optimal K value . Based on the determination of optimal K value, with GCV method, It is obtanied K equals 277. The result of average data of the Semarang sea tidal with reggression nonparametric method showed that R^2 is 95% and MSE = 4,42. The lowest tidal estimation resulted in Semarang is on March 2, 2016. Then the highest tidal estimation in Semarang City occurred on August 31, 2016.

Keywords : Nonparametric Regression, Fourier Series, Tidal Sea

1. Introduction

The method of statistic plays an important role in estimating of sea level. One of methods used in this writing is by regression nonparametric approaching. The regression nonparametric approaching is method of estimating model based on approaching which is not tied to the assumption in the form of certain regression curva. One of regression nonparametric approaching is using Fourier Series. The strength of Fourier Series of regression nonparametric approaching is that it enables to solve the triginometrical distribution data and fluctuiative data pattern, is dependent fluctuating variable value to various independent value (Prahutama, 2013).

Researchs about regression nonparametric approaching of Fourier Series were done previously by Semiati (2010) Developing the estimation model of regression nonparamatic approaching of biresponse Fourier Series, while semiparametic regression using fourier series developed by Asrini (2012), research done by Prahutama (2013) reviewing regression nonparametic model with fourier series in case of opened unemployment level in east java, and research about the modeling of sea tidal in Semarang with local polynominal regression nonparametric approaching by Utami and Nur (2015).

Tidal is sea level fluctuation as time function for the existance of celestial object tensile strenght, especially sun and moon. Sea level rise that maintains increasing, is worried to threaten coastal areas so that causing the financial and economic disadvantage. This will be certainly impacting on sea level. The occurance of subsidence in Semarang also worsens the sea level rise. The subsidence happens because of consolidation and excessively artetic taking (Sarbidi, 2002). This will cause flood in Semarang when the tide is high.

Rob flood occured in Semarang becomes a dissolved problem until today. This is caused the certain number of sea level rise in Semarang is not obvious. Vulnerability research in coastal areas is demanded in order to reduce the impacts and possible responses related to the change of ongoing phenomena. This results in the need for modeling to predict and know how high the sea level is. The result of the modeling is expected to help the concerning parties the strategical steps is needed to be done so that not suffering significant losses. Tidal data shows the pattern of distribution periodic data or fluctuating. Therefore, the appropriate statistical method for tidal modeling tide in Semarang is using the nonparametric regression approach of Fourier series.

1.1 Fourier Series Nonparametic Regression

The method of Fourier series nonparametic regression is the regression method used when the curva is between dependent and independent variable, and Independent variable is not known for the form and pattern. The common nonparametric regression model is as follows

$$y_i = f(x_i) + \varepsilon_i \qquad (1.1)$$

with,
y_i = dependent variable
x_i = independent variable
$f(x_i)$ = regression function

Fourier Series is a trygonometric polynominal function that has flexibility level. This fourier series estimator is generally used when the used data and explored data are not known and there is a seasonal pattern tendency (Tripena and Budiantara, 2006). Fourier Series function in this research is as follows

$$f(t) = \frac{1}{2}a_0 + \gamma t + \sum_{k=1}^{K} a_k \cos\left(\frac{2\pi k t}{2L}\right) \quad (1.2)$$

with
$a_0, a_k \; dan \; b_k$ is fourier coeficient (Asrini, 2012).

The level of estimator graduation of fourier series is determined by graduation parameter election. The lower a estimator graduation of fourier series is, the more graduational the graduation parameter K and the higher graduation parameter is, the more less-gradutional the estimation is from f. Therefore, it is needed to elect The optimal K.

1.2 The Tidal Sea

Tidal is sea level fluctuation as time function for the existance of celestial object tensile strenght, especially sun and moon to sea volume on the earth this tensile strenght is depending from the distance of earth with celestrial objects and their volume. Tidal is the important factor of coastal geomorphology, In this case, It is the neat changing of sea level along the coast and currents formed by tide. In addition, tidal knowledge is important in the planning of coastal buildings, ports and vegetation.

Coastal area is a very dynamic and rich in biological and non-biological natural resources. But coastal areas are more vulnerable to the phenomenon of global warming that causes sea level rise. Coastal areas are areas that will be adversely affected by the global sea level rise phenomenon. Theoretically, sea level rise will inundate some coastal areas, So that causing sea water to continue to land in the direction of land. Coastal areas are a region that is weak or vulnerable by environmental factors such as climate variability, climate change and rising sea levels. Annual sea water rise in Semarang reaches 9,27 mm. The problem of sea level rise is a problem that is noticed after the occurrence of global warming (global warming). Rising global surface temperatures caused the melting of the north and south poles of ice so there was a rise in sea level (Sea Level Rise). It is estimated that from 1999-2100 upcoming sea level rise around 1,4-5,8 m (Dahuri, 2002).

2. Methods

2.1 Data Resources

The main data resourses used in this research is the secondary data served by BMKG. The taken data is the daily data in a year (January 1, 2016 until December 31, 2016).

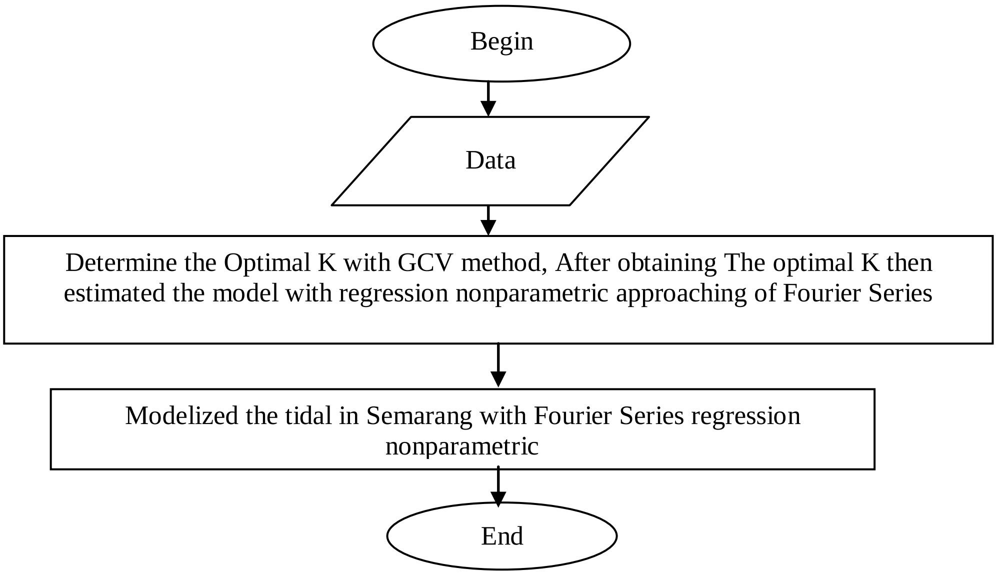
2.2 Research Variable

Table 2.1 Dependent Variable and Independent Variable

Variable	Variable Information	Unit of Measure	Definiton of Counting
Dependent	Tidal	Cm	Counted from everyday rainfall in a year starting from January 1, 2016 until December 31, 2016 in Semarang
Independent	Time	Day	Counted from How many days are from January-December 2016, is 366 days

2.3 Procedures (or research design)

Analysis steps in this research can be described in diagram as described in Flowchart **2.1** below:



Flowchart 2.1 Analysis steps in this research

3. Results

3.1 Determine Optimal K

The first step is to determine the optimal K value The optimal K value is a positive integer. The determination of the optimal K value is using GCV method then running the program of the determination of optimal K value on Tidal in Semarang based on GCV method. The obtained result from the tested K is as follows:

Table 3.1 The Value Using GCV Method to Every Optimal K

K	GCV	K	GCV	K	GCV
7	$1{,}25 \times 10^{+05}$	137	$1{,}32 \times 10^{+02}$	267	$1{,}07 \times 10^{+01}$
17	$2{,}45 \times 10^{+04}$	147	$1{,}12 \times 10^{+02}$	277	$7{,}67 \times 10^{+00}$
27	$9{,}99 \times 10^{+03}$	157	$9{,}44 \times 10^{+1}$	287	$6{,}92 \times 10^{+00}$
37	$5{,}31 \times 10^{+03}$	167	$7{,}90 \times 10^{+01}$	297	$5{,}68 \times 10^{+00}$
47	$2{,}06 \times 10^{+03}$	177	$6{,}84 \times 10^{+01}$	307	$4{,}40 \times 10^{+00}$
57	$1{,}36 \times 10^{+03}$	187	$5{,}95 \times 10^{+01}$	317	$3{,}04 \times 10^{+00}$
67	$9{,}79 \times 10^{+02}$	197	$4{,}49 \times 10^{+01}$	327	$2{,}54 \times 10^{+00}$
77	$7{,}23 \times 10^{+02}$	207	$3{,}66 \times 10^{+01}$	337	$1{,}57 \times 10^{+00}$
87	$5{,}59 \times 10^{+02}$	217	$3{,}27 \times 10^{+01}$	347	$8{,}66 \times 10^{-01}$
97	$3{,}22 \times 10^{+02}$	227	$2{,}76 \times 10^{+01}$	357	$3{,}99 \times 10^{-01}$
107	$2{,}51 \times 10^{+02}$	237	$2{,}44 \times 10^{+01}$	**367**	$\mathbf{3{,}95 \times 10^{-19}}$
117	$2{,}05 \times 10^{+02}$	247	$1{,}59 \times 10^{+01}$		
127	$1{,}67 \times 10^{+02}$	257	$1{,}22 \times 10^{+01}$		

Table 3.1 shows that the Optimal K on the average data of Tidal in Semarang is on K=367 because of the lowest GCV value. By getting K = 367 as the optimal K, so it is known how many parameter must be estimated by 369 parameter. This is obtained based on equation1.2 that is by knowing the amount of the estimated parameter.Therefore, it is known the resulted model to be fulfilled and seen from R^2 for K=1 to K=367.

Table 3.2 R^2 and MSE to Every Optimal K

K	R^2	MSE
277	0.95 (95%)	4.42
287	0,95 (95%)	4.28
297	0,96 (96%)	3.77
307	0,97 (97%)	3.11
317	0,97 (97%)	2.30
327	0,98 (98 %)	2.04
337	0,98 (98%)	1.34
347	0,99 (99%)	0.78
357	0,99 (99%)	0.38
367	1 (100%)	5.24×10^{-07}

Based on **Table 3.2,** it shows that for value K = 277 has resulted R^2 = 95 % which is enough high. The choosen method is a high R^2, low MSE and parsimony model, so the choosen model is **K=277**.

3.2 The Modelizing of Average Tidal Data in Semarang with Fourier Series

After knowing that the optimal K is 277, the next step is to determine the estimation model of tidal with regression nonparametric approaching of Fourier Series. The result of estimated model can be seen on attachment 1. Attachment 1 shows that the obtained model for average tidal data in Semarang as follows :

$$\begin{aligned}\hat{y} &= 62,942 + 0,066t + 0,331\cos t + \\ &0,328\cos 2t - 0,488\cos 3t - \\ &0,395\cos 4t - 0,073\cos 5t + ... - \\ &0,070\cos 277t\end{aligned}$$

4. Discussion

Based on the obtained modelizing, it is known that if (t) = 62, so it can be estimated that average tidal data in Semarang is in the amount of 52,42 cm.The estimation result of the lowest tide in Semarang is the amount of 52,42 cm on March 2, 2016. The estimation result of highest tide in Semarang is the amount of 108,96 cm, on August 31, 2016. The result of the model can be used to forecast the average tidal that will be going to happen in the future by entering how many (t) that can be predicted in the equation .

5. Conclusions

The result of the determination of optimal K with GVC method is K = 277. The result of modelizing that is obtained for the tidal average data in Semarang with R^2 is in the amount of 95% and MSE = 4,42 as follows:

$$\begin{aligned}\hat{y} &= 62,942 + 0,066t + 0,331\cos t + \\ &0,328\cos 2t - 0,488\cos 3t - \\ &0,395\cos 4t - 0,073\cos 5t + ... - \\ &0,070\cos 277t\end{aligned}$$

The estimation result of the lowest tide in Semarang is on March 2, 2016. The estimation result of highest tide in Semarang on August 31, 2016.

6. References

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Attachment 1. Estimated Parameter Model Regression Nonparametric Approaching of Fourier Series

Parameter	Value	Parameter	Value	Parameter	Value	Parameter	Value
α_{0}	62.942	γ	0.066	α_{1}	0.331	α_{2}	0.328
α_{3}	-0.488	α_{4}	-0.395	α_{5}	-0.073	α_{6}	-0.241
α_{7}	0.364	α_{8}	0.149	α_{9}	0.032	α_{10}	0.270
α_{11}	0.451	α_{12}	0.038	α_{13}	-0.488	α_{14}	-0.438
α_{15}	0.114	α_{16}	0.124	α_{17}	0.169	α_{18}	0.560
α_{19}	0.771	α_{20}	0.389	α_{21}	0.343	α_{22}	-0.044
α_{23}	-0.226	α_{24}	0.131	α_{25}	0.335	α_{26}	-0.213
α_{27}	-0.393	α_{28}	-0.657	α_{29}	0.231	α_{30}	0.654
α_{31}	-0.055	α_{32}	-0.944	α_{33}	-0.347	α_{34}	-0.301
α_{35}	-0.248	α_{36}	0.500	α_{37}	0.336	α_{38}	0.201
α_{39}	0.394	α_{40}	0.073	α_{41}	0.210	α_{42}	0.096
α_{43}	0.749	α_{44}	-6.624	α_{45}	-0.502	α_{46}	0.087
α_{47}	-0.159	α_{48}	0.302	α_{49}	0.141	α_{50}	0.860
α_{51}	-0.320	α_{52}	-0.077	α_{53}	-0.222	α_{54}	0.234
α_{55}	-0.207	α_{56}	-0.314	α_{57}	1.269	α_{58}	0.033
α_{59}	-0.013	α_{60}	0.265	α_{61}	0.503	α_{62}	0.476
α_{63}	-0.043	α_{64}	-0.311	α_{65}	0.071	α_{66}	-0.079
α_{67}	-0.183	α_{68}	-0.377	α_{69}	-0.251	α_{70}	-0.258
α_{71}	0.408	α_{72}	-0.254	α_{73}	-0.302	α_{74}	-0.139
α_{75}	-1.027	α_{76}	-0.239	α_{77}	0.400	α_{78}	0.491
α_{79}	0.050	α_{80}	0.466	α_{81}	-0.104	α_{82}	-0.580
α_{83}	-0.114	α_{84}	0.333	α_{85}	0.008	α_{86}	0.286
α_{87}	0.010	α_{88}	4.029	α_{89}	-0.003	α_{90}	0.301
α_{91}	0.441	α_{92}	0.008	α_{93}	0.143	α_{94}	-1.010
α_{95}	-0.351	α_{96}	0.856	α_{97}	0.209	α_{98}	-0.064
α_{99}	-0.137	α_{100}	0.624	α_{101}	1.007	α_{102}	0.433
α_{103}	0.169	α_{104}	-0.119	α_{105}	-0.323	α_{106}	0.053
α_{107}	-0.957	α_{108}	0.332	α_{109}	0.553	α_{110}	0.277
α_{111}	-0.033	α_{112}	0.013	α_{113}	-0.733	α_{114}	-0.223
α_{115}	0.060	α_{116}	-0.042	α_{117}	-0.100	α_{118}	0.022
α_{119}	0.921	α_{120}	0.480	α_{121}	0.460	α_{122}	-0.242
α_{123}	-0.129	α_{124}	-0.492	α_{125}	0.069	α_{126}	-0.063

Parameter	Value	Parameter	Value	Parameter	Value	Parameter	Value
α_{127}	0.319	α_{128}	0.341	α_{129}	0.005	α_{130}	0.242
α_{131}	0.563	α_{132}	-1.564	α_{133}	-0.313	α_{134}	-0.282
α_{135}	-0.491	α_{136}	-0.179	α_{137}	-0.031	α_{138}	-0.332
α_{139}	0.491	α_{140}	0.085	α_{141}	-0.102	α_{142}	-0.353
α_{143}	-0.115	α_{144}	0.410	α_{145}	-0.075	α_{146}	0.236
α_{147}	-0.255	α_{148}	-0.148	α_{149}	-0.244	α_{150}	0.794
α_{151}	-0.145	α_{152}	-0.313	α_{153}	-0.330	α_{154}	0.027
α_{155}	-0.282	α_{156}	0.391	α_{157}	0.537	α_{158}	-0.004
α_{159}	-0.342	α_{160}	0.331	α_{161}	-0.299	α_{162}	0.760
α_{163}	0.828	α_{164}	0.041	α_{165}	-0.134	α_{166}	-0.298
α_{167}	-0.318	α_{168}	-0.139	α_{169}	0.359	α_{170}	0.115
α_{171}	0.277	α_{172}	0.266	α_{173}	0.056	α_{174}	-0.196
α_{175}	0.465	α_{176}	0.642	α_{177}	-0.170	α_{178}	-0.051
α_{179}	0.275	α_{180}	0.211	α_{181}	0.415	α_{182}	-0.378
α_{183}	0.025	α_{184}	-0.399	α_{185}	-0.288	α_{186}	-0.146
α_{187}	0.470	α_{188}	0.266	α_{189}	0.698	α_{190}	0.260
α_{191}	0.211	α_{192}	0.455	α_{193}	0.353	α_{194}	0.088
α_{195}	-1.939	α_{196}	-0.717	α_{197}	0.028	α_{198}	0.349
α_{199}	0.509	α_{200}	-0.344	α_{201}	-1.333	α_{202}	-0.152
α_{203}	-0.688	α_{204}	0.101	α_{205}	-0.060	α_{206}	0.173
α_{207}	0.134	α_{208}	-0.234	α_{209}	0.004	α_{210}	0.556
α_{211}	0.221	α_{212}	0.126	α_{213}	-0.156	α_{214}	-0.116
α_{215}	0.060	α_{216}	0.118	α_{217}	-0.008	α_{218}	0.000
α_{219}	-0.589	α_{220}	-1.047	α_{221}	0.093	α_{222}	0.242
α_{223}	0.278	α_{224}	0.023	α_{225}	-0.235	α_{226}	-0.050
α_{227}	-0.116	α_{228}	-0.047	α_{229}	0.294	α_{230}	0.335
α_{231}	-0.019	α_{232}	-0.110	α_{233}	-0.390	α_{234}	-0.036
α_{235}	0.513	α_{236}	-0.363	α_{237}	0.105	α_{238}	-0.334
α_{239}	0.588	α_{240}	0.650	α_{241}	0.321	α_{242}	0.022
α_{243}	-0.120	α_{244}	-0.319	α_{245}	2.238	α_{246}	-0.389
α_{247}	-0.073	α_{248}	0.038	α_{249}	-0.208	α_{250}	-0.193
α_{251}	0.993	α_{252}	0.489	α_{253}	0.510	α_{254}	0.164
α_{255}	-0.278	α_{256}	-0.541	α_{257}	-0.723	α_{258}	-0.108

Parameter	Value	Parameter	Value	Parameter	Value	Parameter	Value
α_{259}	0.162	α_{260}	0.405	α_{261}	0.150	α_{262}	0.144
α_{263}	0.059	α_{264}	0.269	α_{265}	0.180	α_{266}	-0.577
α_{267}	-0.074	α_{268}	-0.302	α_{269}	-0.144	α_{270}	1.155
α_{271}	0.450	α_{272}	0.053	α_{273}	-0.363	α_{274}	-0.720
α_{275}	-0.313	α_{276}	0.486	α_{277}	-0.070		