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MODELING OF LOCAL POLYNOMIAL KERNEL NONPARAMETRIC REGRESSION FOR COVID DAILY CASES IN SEMARANG CITY, INDONESIA

Tiani Wahyu Utami[1], Aisyah Lahdji[2]
[1]Program Study of Statistics, Universitas Muhammadiyah Semarang
[2]Medical Faculty, University Muhammadiyah Semarang

e-mail: tianiutami@unimus.ac.id

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Abstract: Coronavirus disease 2019 (COVID-19) is an infectious disease caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) which was recently discovered. Coronavirus disease is now a pandemic that occurs in many countries in the world, one of which is Indonesia. One of the cities in Indonesia that has found many COVID cases is Semarang city, located in Central Java. Data on cases of COVID patients in Semarang City which are measured daily do not form a certain distribution pattern. We can build a model with a flexible statistical approach without any assumptions that must be used, namely the nonparametric regression. The nonparametric regression in this research using Local Polynomial Kernel approach. Determination of the polynomial order and optimal bandwidth in Local Polynomial Kernel Regression modeling use the GCV (Generalized Cross Validation) method. The data used this research are data on the number of COVID patients daily cases in Semarang, Indonesia. Based on the results of the application of the COVID patient daily cases in Semarang City, the optimal bandwidth value is 0.86 and the polynomial order is 4 with the minimum GCV is 3179.568 so that the model estimation results the MSE is 2922.22 and the determination coefficient is 97%. The estimation results show the highest number of Corona in the Semarang City at the beginning of July 2020. After the corona case increased in July, while the corona case in August decreased.

1. INTRODUCTION

At the beginning of 2020, the world was shocked by the outbreak of the corona virus (Covid-19) which has infected almost all people in the world. World Health Organization (WHO) Since January 2020 has declared the world into a global emergency related to this virus (Sebayang, 2020). This is an extraordinary phenomenon that occurs on earth in the 21st century, whose scale may be comparable to that of World War II, because large-scale events (international sports competitions for example) are almost entirely postponed or even canceled. This situation has occurred only during the world war, there has never been any other situation canceled these events. As of March 19, 2020, the Corona virus update in the

world was 214,894 people were infected with the corona virus, 8,732 people died and 83,313 patients had recovered (Aida, 2020). Based on data from the WHO, June 30, 2020, there were 216 country cases with confirmed cases of covid-19 (WHO, 2020). Indonesia is one of the countries confirmed to have been exposed to Covid-19 which entered in early March 2020. According to data released by the Covid-19 Handling Acceleration Group on June 30, 2020, there were 56,385 positive exposures to the virus, data for covid-19 in Indonesia is still volatile (Fitra, 2020). At the beginning of the emergence of Covid-19 in Indonesia, the government has made various policy efforts arising from the virus, ranging from health, social, economic and other fields.

Coronavirus disease (COVID) is an infectious disease caused by the severe acute respiratory syndrome coronavirus 2 (SARS-CoV-2) or the so-called Corona virus which was recently discovered. COVID-19 is now a pandemic that occurs in many countries in the world, one of which is Indonesia. Central Java City is an area in Indonesia that has found many corona cases. The highest number of COVID 19 cases in Central Java is Semarang City. Since April 9 until August 7, 516 COVID -19 cases were reported in Semarang City in Indonesia (Adelia, 2020). COVID case data in Semarang City does not form a specific distribution pattern.

Regression analysis was developed to determine the relationship and influence of the predictor variables on the response variable by estimating the regression curve function. Regression analysis can be carried out with three approaches, namely the parametric, nonparametric, and semiparametric approaches. We can build a model with a flexible statistical approach without any assumptions, namely the nonparametric regression models. Several nonparametric regression approaches that are often used include Spline Truncated, Fourier Series, Local Polynomial Kernel estimator and others. The nonparametric regression approach in this research was carried out using Local Polynomial Kernel. In regression modeling by Local Polynomial Kernel approach, the determination of the optimal bandwidth and the polynomial order uses the Generalized Cross Validation (GCV) method. The advantage of local kernel polynomial estimator is that it can reduce the asymptotic bias and produce good estimates (Fan & Gijbels, 1998). Kernel Local Polynomial estimator can be obtained by Weighted Least Square (WLS) optimization. Meanwhile, to estimate smoothing parameters (bandwidth) using the GCV method. The regression curve estimator is obtained by estimating its parameters (Utami et al., 2019). The GCV method is better than the UBR method (Utami et al., 2020).

Previous research has been developed including the estimation of nonparametric regression models in cases of dengue fever based on local polynomial estimators of the GEE kernel (Utami & Nur, 2014) . Another research on longitudinal data modeling using semiparametric regression of Local Polynomial (Utami, 2013). Daily covid case data in the city of Semarang does not form a specific distribution pattern so it is carried out with a nonparametric approach, namely the Local Polynomial Kernel. This study discussed the modeling of Local Polynomial Kernel Nonparametric Regression for Novel Coronavirus daily cases in Semarang City, Indonesia.

The city of Semarang was chosen as the research location because it is a busy city center in Central Java province. The background for the selection of Semarang City is that Semarang City is one of the Covid-19 Red Zones since it was established at the end of February 2020. In addition, Semarang City is also the link between West Java and East Java through the North Coast Line (Pantura) where many vehicles pass through and become one of the main routes for domestic and international flights in Central Java Province.

2. LITERATURE REVIEW

2.1. Local Polynomial Nonparametric Regression

Nonparametric regression is a method used to estimate the pattern of the relationship between the response variable and the predictor variable. Given data $(x_i, y_i), i = 1,2,..n$ where n is the number of subjects. The x_i is the predictor variable observed from the i^{th} subject. The relationship between these variables is stated in the nonparametric regression model as follows:

$$y_i = \eta(x_i) + e_i; i = 1,2,..n \quad (1)$$

The function $\eta(x_i)$ is a function that has no known form called a regression function (Wu & Zhang, 2006). Where $e_{ij} \sim N(0, \sigma^2)$) is the measurement error. It is known that x is the predictor variable so that the function η is estimated using the Local Polynomial Kernel approach. With the Taylor series, $\eta(x_i)$ in equation (1) can be approximated by a polynomial of degree p as follows:

$$\eta(x_i) \approx \eta(x) + (x_i - x)\eta^{(1)}(t) + \cdots + (x_i - x)^p \eta^{(p)}(x)/p! \quad (2)$$

$$x_i \in [x - h, x + h]$$

Suppose $\beta_r(x) = \eta^{(r)}(x)/r!; r = 0,1,2, \ldots, p$ then (2) can be written as:

$$\eta(x_i) \approx \beta_0(x) + (x_i - x)\beta_1(x) + \cdots + (x_i - x)^p \beta_p(x)$$

2.2. Kernel Function

In general, the Kernel K_h function with bandwidth (smoothing parameter) h is defined:

$K_h(x) = \frac{1}{h} K\left(\frac{x}{h}\right)$; For $-\infty < x < \infty$ and $h > 0$, satisfies the following properties:

(i) $K(x) \geq 0$

(ii) $\int_{-\infty}^{\infty} K(x)dx = 1$

(iii) $\int_{-\infty}^{\infty} xK(x)dx = 0$

(iv) $\int_{-\infty}^{\infty} x^2 K(x)dx = \sigma^2 > 0$

Kernel function used in this study (Hardle, 1990) is Kernel Gaussian

$$K(x) = \frac{1}{\sqrt{2\pi}} \exp\left(\frac{1}{2}\left(-x^2\right)\right) \quad (3)$$

2.3. Smoothing Parameter Selection Method

Smoothing parameter (bandwidth) controls the balance between smoothness of function and suitability of function to data. Selection of optimal bandwidth *(h)* is very important so that the estimator obtained is also optimal. Bandwidth that is too small will result in a less smooth estimation curve, that is, the estimation results will go to the data, on the other hand, too large a bandwidth will produce a very smooth estimation curve and lead to the average of the response variable Therefore, choosing the right bandwidth is very important in regression analysis (Budiantara & Mulianah, 2007; Hadijati, 2004). This means that for every *h* there is a matrix $\boldsymbol{A}$ of size $n \times n$ so that: $\hat{\boldsymbol{y}} = \boldsymbol{Ay}$ **.**

One method for obtaining optimal h is by using the Generalized Cross Validation (GCV) method which is defined as follows (Hong, 1999):

$$GCV(h) = \frac{MSE(h)}{(n^{-1}tr[\boldsymbol{I} - \boldsymbol{A}])^2} \quad (4)$$

Where,

$$MSE(h) = n^{-1}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2$$

The optimal *h* value is obtained from h which results in the minimum GCV value.

2.4. Corona Virus Disease 19 (Covid-19)

Corona Virus Disease 19 (Covid-19) was first known at the end of 2019 at Wuhan city of China. This virus attacks the respiratory system with symptoms such as pneumon. This virus is a relatively new virus, so it doesn't have one antidote and this virus has spread all over the world until it gets out of control. It has been recorded that more than 200 countries have reported cases of COVID-19, including Indonesia (Wikipedia, 2019). In the current conditions the corona virus has been established by WHO as a pandemic (WHO, 2020). The spread of Covid-19 has entered Indonesia since March 2, 2020.

Indonesia is a developing country which is the fourth most populous country in the world. Therefore, Indonesia has a fairly high risk and is expected to go through a fairly difficult and long time to deal with the threat of COVID-19 compared to other countries (Djalante et al., 2020). The Central Java Provincial Government (Pemprov) records the number of the latest corona virus cases on Tuesday, July 28, 2020 at 12.00 WIB. Through its official website corona.jatengprov.go.id, the Central Java Provincial Government provides information on corona virus case data. The site recorded 8,795 people infected with the corona virus, and 4,902 people had been declared cured. In the Central Java region there were also 750 patients who died from this virus. So that as many as 3,143 people are still being treated at the hospital designated to treat corona virus patients. There are also 546 people in the monitoring site (ODP) who are currently in the monitoring process in Central Java.

3. MATERIAL AND METHOD

3.1. Material of Research

This research uses secondary data. This data obtained from the Siaga Corona Kota Semarang in 2020. In this study, 121 days of Coronavirus case observation were used from 9 April 2020 to 7 August 2020 in Semarang City, Central Java Province, Indonesia. The variables used in the study were one response variable and one predictor variable. The response variable is COVID patients daily cases. The predictor variable is the time of observation.

3.2. Methodology of Research

The analysis steps used in this research are:

a. estimation of the local polynomial kernel nonparametric regression model.
b. create a scatterplot of coronavirus daily new cases.
c. create algorithms and programs to determine the polynomial orde and the optimal bandwidth value by minimizing the GCV value
d. after obtaining the optimal polynomial order and bandwidth, then make algorithms and programs for estimating nonparametric regression models using the Kernel Local Polynomial approach.

e. modeling of Novel Coronavirus daily cases in Semarang City using nonparametric regression with Local Polynomials Kernel approach

4. RESULTS AND DISCUSSION

4.1. Estimation of the Local Polynomial Kernel Nonparametric Regression Model

Given *n* objects of data, (t_i, y_i), *i = 1,2,...,n* ; follows a nonparametric regression model which is stated as follows:

$$y_i = \eta(t_i) + e_i \ , \ i = 1,2,3...n \tag{5}$$

The function $\eta(t_i)$ unknown so it is estimated using the estimator Local Polynomial Kernel (LPK). The estimator $\eta(t_i)$ in the i^{th} object is

$$\hat{\eta}(t_i) \approx \hat{\beta}_{0i} + (t_i - t)\hat{\beta}_{1i} + (t_i - t)^2 \hat{\beta}_{2i} + ... + (t_i - t)^p \hat{\beta}_{pi} \tag{6}$$

The model in (6) can be written into a matrix as follows:

$$\hat{\eta}(t_i) \approx x_i^T \hat{\beta}_i, i = 1,2,...,n \tag{7}$$

The method used to estimate the parameters of the kernel local polynomial regression model is Weighted Least Square (WLS). $\hat{\beta}_i$ value of equation (7) is obtained by minimizing the Weigthted Least Square (WLS):

$$WLS = (\boldsymbol{y} - \boldsymbol{X\beta})^T \mathbf{K_h} (\boldsymbol{y} - \boldsymbol{X\beta})$$

The minimum value of WLS was achieved at $\frac{\partial WLS}{\partial \beta_i} = 0$, then:

$$-2\mathbf{X^T K_h} y + 2\mathbf{X^T K_h X}\hat{\beta}_i = 0$$

$$\mathbf{X^T K_h X}\hat{\beta}_i = \mathbf{X^T K_h} y$$

$$\hat{\beta}_i = (\mathbf{X^T K_h X})^{-1} \mathbf{X^T K_h} y$$

Equation (6) becomes as follows: $\hat{\eta}(t) = \mathbf{A}y$, where $\mathbf{A} = \mathbf{X(X^T K_h X)^{-1} X^T K_h}$.

4.2. Model Scatterplot of Novel Coronavirus Daily Cases in Semarang City Indonesia

The data used for the application of the local polynomial kernel nonparametric regression model is the number of daily cases of coronavirus. What is done to obtain nonparametric regression modeling using the LPK approach is to create a scatterplot of data on the Covid cases in Semarang City. The first step to obtain nonparametric regression modeling using the LPK approach is to create a scatterplot of the Covid case data in Semarang City. The following is a scatterplot of Coronavirus daily cases in Semarang City Central Java with observations from 9 April 2020 to 7 August 2020:

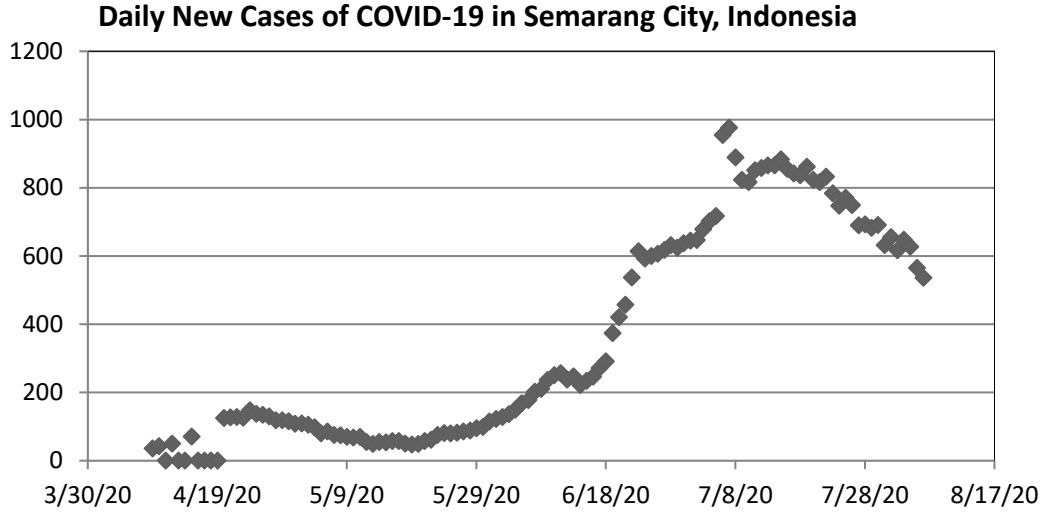

Figure 1. Scatterplot of Novel Coronavirus Daily Cases in Semarang City, Indonesia

Based on the Graph of Novel Coronavirus Daily Cases, it can be said that Figure 1 with the number of COVID cases in Semarang City shows that it does not form a certain pattern so that the modeling is approached by nonparametric regression with the local polynomial kernel approach. Data were obtained from Siaga Corona Kota Semarang in 2020 with daily observations from 9 April 2020 to 7 August 2020. The highest number of COVID cases was in Semarang in early July 2020. The response variable in this study was the number of COVID cases in Semarang City. While the predictor variable in this study is the time of observation. COVID case data in Semarang City does not form a specific distribution pattern.

4.3. Nonparametric Regression Algorithm and Programming with Local Polynomial Kernel Approach

Algorithms for programming using R software are used to estimating the nonparametric regressio Local Polynomial Kernel approach, namely:

A. The algorithm to determines the smoothing parameter and the polynomial order

Create algorithms to determine the polynomial order (p) and the smoothing parameter or bandwidth optimal (h) value by minimizing the GCV value are as follows :

1. Given response variable ($\boldsymbol{y}$) is COVID patients daily cases and the variable ($\boldsymbol{x}$) is the time of observation.
2. Determine the kernel function to be used
3. Determine p and the h value using the $GCV(h)$ method. For each $h \in$ [bb,ba] and p, calculate value of $GCV(h)$ as follows:
   a. Get the matrix $\mathbf{A} = \mathbf{X}(\mathbf{X}^{\mathrm{T}}\mathbf{K}_{\mathrm{h}}\mathbf{X})^{-1}\mathbf{X}^{\mathrm{T}}\mathbf{K}_{\mathrm{h}}$
   b. Determine the vector $\hat{\boldsymbol{y}} = \mathbf{A}\boldsymbol{y}$
   c. Determine the value of $GCV(h) = \frac{N^{-1}\boldsymbol{y}^{T}(\mathbf{I}-\boldsymbol{A})^{T}(\mathbf{I}-\boldsymbol{A})\boldsymbol{y}}{(N^{-1}trace[\mathbf{I}-\boldsymbol{A}])^{2}}$
4. Determine the local polynomial order p and the optimal bandwidth value from step 3 simultaneously. The optimal h value is obtained from h which results in the minimum GCV value.

B. The algorithms for estimating nonparametric regression models using the Kernel Local Polynomial approach

After obtaining the optimal polynomial order and bandwidth, then make algorithms for estimating nonparametric regression models using the Kernel Local Polynomial approach are as follows:

1. Given response variable ($\boldsymbol{y}$) is COVID patients daily cases and the variable ($\boldsymbol{x}$) is the time of observation
2. Determine Kernel function
3. Input the optimal *h* and polynomial order
4. Get the matrix $\mathbf{A} = \mathbf{X}(\mathbf{X}^{\mathbf{T}}\mathbf{K}_{\mathbf{h}}\mathbf{X})^{-1}\mathbf{X}^{\mathbf{T}}\mathbf{K}_{\mathbf{h}}$
5. Get the vector $\hat{\boldsymbol{y}} = \mathbf{A}\boldsymbol{y}$
6. Calculate value $\mathbf{e} = \mathbf{y} - \hat{\mathbf{y}}$
7. Compute value $MSE(h)$, with $MSE(h) = n^{-1}\sum_{i=1}^{n}(y_i - \hat{y}_i)^2$
8. Calculate the R-Square value

4.4. Optimal Bandwidth *(h)* Selection

The first step before estimating the regression model is determining the smoothing parameter (bandwidth) and polynomial order. The Generalized Cross Validation (GCV) method is a method used in determining it. The first step in this research is to choose the optimal h value and the polynomial order (p). This value is used as a reference in estimating the nonparametric regression model on the data on the number of positive sufferers of Coronavirus or COVID 19 in Semarang City. The application of the GCV method is to take the minimum value. Algorithms and programs for determining it order are run so that the results are as shown in Table 1.

Table 1. Selection of Smoothing Parameter (*h*) and Polynomial Order (*p*)

Polynomial Order (p)	*h*	GCV
1	0.88	23241.06
2	0.96	22351.53
3	1.06	11370.92
4	**0.86**	**3179.57**

In the data on the number of positive patients with the Coronavirus or COVID 19 in Semarang City based on table 1, the polynomial order is obtained with a minimum GCV value of 3179.57, with a bandwidth value (*h*) of 0.86. Thus, the nonparametric regression model for data on the number of positive patients with the Coronavirus or COVID 19 in Semarang City is approached with a Local Polynomial with an initial bandwidth value of 0.86 and a polynomial order of p = 4.

4.5. Modeling of Novel Coronavirus Daily Cases Using Local Polynomial Kernel Nonparametric Regression

The optimum bandwidth chosen is 0.86 while the polynomial order is 4. After this value is obtained, then determining the estimation of each parameter by running the algorithm and program estimating nonparametric regression models using the Kernel Local Polynomial approach. The following are the estimation results for each parameter of the nonparametric regression model of the local polynomial kernel:

Table 2. Estimation Results of Nonparametric Regression Model Parameters Using Local Polynomial Kernel Approach

Parameter	Value
$\hat{\beta}_0$	672.812
$\hat{\beta}_1$	-19.059
$\hat{\beta}_2$	-0.219
$\hat{\beta}_3$	-0.011
$\hat{\beta}_4$	-8.611 x10^{-5}

After obtaining the parameter estimation results, a nonparametric regression modeling of the local polynomials kernel can be formed as follows:

$$\hat{\eta}(t_i) \approx x_i^T \hat{\beta}_i, i = 1,2,...,n$$

The following is the equation for result estimation modeling of Coronavirus daily cases using Polynomial Lokal Kernel nonparametric model as follows:

$$\hat{\eta}(t_i) \approx \hat{\beta}_{0i} + (t_i - t)\hat{\beta}_{1i} + (t_i - t)^2 \hat{\beta}_{2i} + .(t_i - t)^3 \hat{\beta}_{3i} + (t_i - t)^4 \hat{\beta}_{4i}$$

$$\hat{\eta}(t_i) \approx \hat{\beta}_{0i} + (t_i - 85)\hat{\beta}_{1i} + (t_i - 85)^2 \hat{\beta}_{2i} + .(t_i - 85)^3 \hat{\beta}_{3i} + (t_i - 85)^4 \hat{\beta}_{4i}$$

$$\hat{\eta}(t_i) \approx 672.812 - (t_i - 85)19.059 - (t_i - 85)^2 0.219 - .(t_i - 85)^3 0.011 - (t_i - 85)^4 (8.611 \text{x} 10^{-5})$$

4.6. Comparison of Prediction Results with Actual Data

After knowing the equation Modeling of Coronavirus Daily Cases using Local Polynomial Kernel, the next step is to compare the result estimation of daily cases of coronavirus patient based on the results of nonparametric regression modeling of local kernel polynomials with actual data. The smooth graphic display is the estimation result of modeling, while the dotted shape is the actual data from COVID patients daily cases. The following is a graph of the predicted data with actual data:

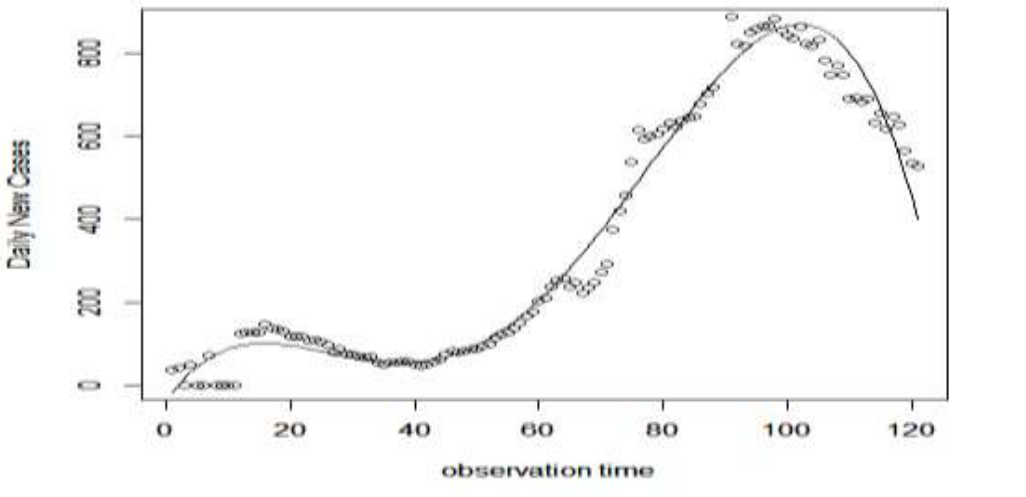

Figure 2. Graph of Estimation Result for Coronavirus Daily Cases Modeling using Polynomial Lokal Kernel

Based on Figure 2, it can be concluded that the dynamics of the pattern change are the same between the actual data and the predicted data. It can be stated that the modeling obtained is suitable for predicting Coronavirus cases in the Semarang City. The estimation results show the highest number of Corona in the Semarang City at the beginning of July 2020. After the corona case increased in July, while the corona case in August decreased.

The ability to evaluate the accuracy of the model can be shown in the determination coefficient (R^2) and the Mean Square Error (MSE) value. The model is said to be better if the determination coefficient approaches 100% and MSE value is getting smaller. The processed results using the local polynomial kernel nonparametric regression approach applied to the Novel Coronavirus daily cases data in the Semarang City shows a determination coefficient of 0,97 and MSE of 2926,67. Determination coefficient of 97% means that the predictor variable, namely the time of observation, can explain a number of COVID patients daily cases in Semarang City by 97%, while 3% is influenced by other variables not used in this research.

5. CONCLUSION

Modeling Novel Coronavirus daily cases using Kernel Local Polynomial Nonparametric Regression produces the following equation:

$$\hat{\eta}(t_i) \approx \hat{\beta}_{0i} + (t_i - t)\hat{\beta}_{1i} + (t_i - t)^2 \hat{\beta}_{2i} + .(t_i - t)^3 \hat{\beta}_3 + (t_i - t)^4 \hat{\beta}_{4i}$$

$$\hat{\eta}(t_i) \approx \hat{\beta}_{0i} + (t_i - 86)\hat{\beta}_{1i} + (t_i - 86)^2 \hat{\beta}_{2i} + .(t_i - 86)^3 \hat{\beta}_3 + (t_i - 86)^4 \hat{\beta}_{4i}$$

$$\hat{\eta}(t_i) \approx 831.023 - (t_i - 86)13.065 - (t_i - 86)^2 1.259 - .(t_i - 86)^3 0.019 - (t_i - 86)^4 (8.416 \text{x} 10^{-5})$$

The regression model has a determination coefficient (R^2) of 0.97 (97%) and an MSE value of 2922.22. This shows that the observation time can explain the variance of the number of COVID patients daily cases by 97% and 3% is influenced by other variables not used in this research.

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REFERENCES

Adelia, L. (2020). *Update Virus Corona Kota Semarang Jumat 7 Agustus 2020, Tertinggi Tembalang Terendah Tugu*. Tribun Jateng. https://jateng.tribunnews.com/2020/08/07/update-virus-corona-kota-semarang-jumat-7-agustus-2020-tertinggi-tembalang-terendah-tugu?page=4

Aida, N. . (2020). *Update Virus Corona di Dunia: 214.894 Orang Terinfeksi, 83.313 Sembuh, 8.732 Meninggal Dunia*. Kompas.Com. https://www.kompas.com/tren/read/2020/03/19/081633265/update-virus-corona-didunia-214894-orang-terinfeksi-83313-sembuh-8732

Budiantara, I. ., & Mulianah. (2007). Pemilihan Banwidth Optimal dalam Regresi Semiparametrik Kernel dan Aplikasinya. *Journal Sains Dan Teknoogi SIGMA*, *10*,

159–166.

Djalante, R., Lassa, J., Setiamarga, D., Sudjatma, A., Indrawan, M., Haryanto, B., Mahfud, C., Sinapoy, M. S., Djalante, S., Rafliana, I., Gunawan, L. A., Surtiari, G. A. K., & Warsilah, H. (2020). Review and Analysis of Current Responses to COVID-19 in Indonesia: Period of January to March 2020. *Progress in Disaster Science*, *6*. https://doi.org/10.1016/j.pdisas.2020.100091

Fan, J., & Gijbels, I. (1998). *Local Polynomial Modelling and its Aplications*. Chapman and Hall.

Fitra, S. (2020). *Perkembangan Terkini COVID-19 di Indonesia : Total Kasus Capai 56.385*. Katadata. https://databoks.katadata.co.id/datapublish/2020/06/30/Perkembangan-Terkini-Covid-19-di-Indonesia-Total-Kasus-Capai-56385-Kasus-Selasa-306

Hadijati, M. (2004). *Estimasi Kernel dalam Regresi Nonparametrik dengan Error Berkorelasi*. Institut Teknologi Sepuluh Nopember, Surabaya.

Hardle, W. (1990). *Applied Nonparametric Regression*. Cambridge University Press.

Hong, S. Y. (1999). Automatic bandwidth choice in a semiparametric regression model. *Statistica Sinica*, *9*(3), 775–794.

Sebayang, R. (2020). *Awas! WHO Akhirnya Tetapkan Corona Darurat Global*. CNBC Indonesia.

Utami, T. . (2013). Estimasi Kurva Regresi Semiparametrik Pada Data Longitudinal Berdasarkan Estimator. *Statistika*, *1*(1), 30–36.

Utami, T. ., & Nur, I. . (2014). Longitudinal Data Modeling Based on Platelets Level in DHF (Dengue Hemorrhagic Fever) Using Nonparametric Regression of Local Polynomial Kernel GEE Approach. *International Conference on Biomedical Engineering Technology and Application (ICBETA)*.

Utami, T. W., Haris, M. A., Prahutama, A., & Purnomo, E. A. (2020). Optimal Knot Selection in Spline Regression using Unbiased Risk and Generalized Cross Validation Methods. *Journal of Physics: Conference Series*, *1446*(1). https://doi.org/10.1088/1742-6596/1446/1/012049

Utami, T. W., Prahutama, A., Karim, A., & Achmad, A. R. F. (2019). Modelling Rice Production in Central Java using Semiparametric Regression of Local Polynomial Kernel Approach. *Journal of Physics: Conference Series*, *1217*(1). https://doi.org/10.1088/1742-6596/1217/1/012108

WHO. (2020). *Coronavirus Disease 2019 (COVID-19): Situation Report*.

Wikipedia. (2019). *Coronavirus Disease 2019*. Wikipedia. https://en.wikipedia.org/wiki/Coronavirus_disease_2019

Wu, H., & Zhang, J. (2006). *Nonparametric Regression Methods for Longitudinal Data Analysis : Mixed- Effects Modeling Approaches Nonparametric Mixed-Effects Models for Longitudinal Data Analysis* (Issue March). https://doi.org/10.1002/0470009675