A Comparison between Simple Linear Regression and Radial Basis Function Neural Network (RBFNN) Models for Predicting…

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Transforming Ideas into Reality

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A COMPARISON BETWEEN SIMPLE LINEAR REGRESSION AND RADIAL BASIS FUNCTION NEURAL NETWORK (RBFNN) MODELS FOR PREDICTING STUDENTS' ACHIEVEMENT

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Abstract

This paper presents an approach for predicting student achievements using statistics and artificial neural networks (ANN), namely linear regression and radial basis function neural network (RBFNN) methods. The data is gained from 108 students from mathematics department in Islamic University, Bengkulu, Indonesia. The results of measurement are then compared to the value of the mean of square error (MSE). The results show that MSE 0.076 with model Y = 3.193 + 0.002 for linear regression and MSE 0.003, model Y = (1)T + (0.0021) with sum-squared error goal 0.01, and spread 1 for the RBFNN. The smallest MSE value indicates a good method for accuracy. Therefore, the RBFNN model illustrates the proposed best model to predict students' achievement.

Keywords: simple linear regression, ANN, RBFNN, MSE, student achievement

INTRODUCTION

Researchers widely and mostly employ the analysis model that combines statistical methods and artificial neural networks (ANNs). Thus, the use of these combined methods broadly used in finance, demography, and weather. In analysis scheme, the use of combination methods is influenced by the pattern of analysis models of particular data because each method has different sequences.

The analysis model results that have high accuracy and good are very significant in decision-making; for example for predicting, designing and creating (Donate, Sanchez, & Miguel, 2012; Valipour, Banihabib, & Behbahani, 2013). Hence, the main factor affecting the selection of analyzing model techniques is to identify and determine based on the data characteristics.

Time-series is part of data characteristics that consist of four features. They are (1) trend (T) that data have characteristics that tend to go up and down; (2) seasonal variation (S) means that type of data in the annual periodic fluctuations such as month, week and day; (3) cycles (C) refers to periodic fluctuations in the data type more than one year and; (4) random component (R) means a type of time series which is a combination of seasonal variation, trends, cycles and random factors (Chung-Fu, 2011; Ferrari-Santos, Simões da-Silva, de-Sá Silva, & da-Costa Sene, 2011; Wei, 2006). Furthermore, a time series consists of a set of observations based on time. In principle, time series are used to analyze a set of data $(y_{t+1}, y_{t+2}, \ldots, y_{t-n})$ based on the data $(x_{t+1}, x_{t+2}, \ldots, x_{t-n})$ in a certain time frame (Box, Jenkins, & Reinsel, 2008; Donate et al., 2012; Zhang, 2003).

In this paper, simple linear regression statistical and RBFNN have been used to analyze model using trend data characteristics. This article consists of four sections. Introduction section is the motivation to do the writing of the article. Next, the literature related to the theory and techniques in forecasting time series is discussed in literature review section. Method and sampling section presents the experimental results, and finally finding and discussion section describes the discussion results and research summaries.

LITERATURE REVIEW

The analysis model is the first activity of modeling what will happen in the next stage based on previous data. In this paper, we conducted an comparison using the simple linear regression and RBFNN methods to analyze a model of student achievement based on learning motivation data. Next, we describe briefly about simple linear regression, RBFNN technique and learning motivation.

Simple Linear Regression

The simple linear regression is a way of modeling the relationship between variables in statistical analysis (Cohen, Manion, & Morrison, 2010). The objective of regression analysis is to predict a single dependent variable from the knowledge of one or more independent variables (Hair et al., 2010). When the model includes one explanatory variable (the independent variable) and one explained variable (the dependent variable), the statistical technique is called simple linear regression. The equation of simple linear regression is:

$$Y = a + bx$$

Where:
Y: $dependent\ variable$
a : $constant$
b : $coefficient\ variable$
x : $independent\ variable$

In using regression techniques, it is important to be aware of certain assumptions underpinning them. The assumptions should be fulfilled are normality, multicollinearity, linearity and outliers. After all of the assumptions are fulfilled, the analysis can be run.

The normality of the data can be assessed by checking the measures of skewness and kurtosis. The measure of skewness is a measure of the asymmetry of a distribution. The normal distribution is symmetric and has a skewness value of 0. The measure of kurtosis indicates the extent to which the scores are "bunched" around the mean. The measures of skewness and kurtosis which is close to 0 indicate that the distribution of scores is considered approximately normal (Argyrous, 2011). In addition, to run the regression analysis, normality of the residuals for the dependent variable (the differences between calculated and observed scores) must be met. Kolmogorov-Smirnov test is used to assess the normality of the residuals for the dependent variable.

To determine the multicollinearity, Tolerance and Variance Inflation Factor (VIF) value in SPSS output can be used (Hair, Black, Babin, & Anderson, 2010). Tolerance is an indicator of how much of the variability of the specified independent is not explained by the other independent variables in the model while VIF is the inverse of the Tolerance value (Pallant, 2011). If Tolerance value is not less than 0.1 or VIF value is less than 10 then there is no multicollinearity between independent variables.

To assess the linearity and outliers, the scatterplot between standardized residual value and standardized prediction value is used. If the plot between standardized residual value and standardized prediction value does not make a pattern then the model is considered linear. If there are no standardized residuals that more than 3.3 or less than -3.3 then the assumption of outliers are considered fulfilled (Tabachnick & Fidell, 2007).

Artificial Neural Networks (ANNs)

Today, artificial intelligence (AI) has influenced our life. Along with the development of software and hardware, since 1990's AI continues to evolve and be used to solve various problems in the real world (Khashei & Bijari, 2010). Technically, the existing AI grouped into: (1) searching, is used to search the optimum, (2) reasoning, reasoning, using reasoning in the results, (3) planning, generally used in manufacturing and robotic world, and (4) learning, use of ANNs has been trained to a conclusion (Gomes & Ludermir, 2013).

ANNs is the abbreviation of artificial neural networks and a part of AI. An ANNs is a computational models inspired in the natural neurons (Badiru & Cheung, 2002; Buchanan, 2005) and influenced by ideas from many disciplines (Basheer & Hajmeer, 2000). Warren McCulloch and Walter Pitts in 1943 introduced a simple of neural networks. They proposed assigning weights in the network are set to perform simple logic function, called propagation function. Then, the propagation function results of weight are compared with the threshold functions, generated by the activation function. Then also, the combination of several simple neurons into a system will enhance the ability of neural computation. In principles, useful or not an ANNs are determined by weight training results.

Radial Basis Function Neural Network (RBFNN)

The RBFNN emerged as a variant of ANN in late 80’s is a kind of feed-forward neural network (FFNN). The RBFNN structure has a three-layer FFNN which includes an input layer, a hidden layer with RBF neurons and an output layer with linear neurons. Hence, RBFNN has a unique training algorithm consists of supervised and unsupervised as well (Wu-Yu & Yu, 2012). The architecture of RBFNN as shown in Figure 1. Then, the RBFNN equation is

$$Y = \sum_{j=1}^{m} W_{jm} . \varphi$$

Where: $Y = output\ value$; $\varphi = hidden\ layer\ value$; $W = weights\ (0 - 1)$.

The algorithm of RBFNN to analyze within time series data characteristics is:

1. Initialization of the network.
2. Determining the input signal to hidden layer, and find D_{ij} is a distance data i to j where $i, j = 1,2, \dots, Q$

$$D_{ij} = \sqrt{\sum_{k=1}^{R} (p_{ik} - p_{jk})^2}$$

3. Find $a1$ is a result activation from distance data multiply bias.

$$a1_{ij} = e^{-(b1 * D_{ij})^2} \text{ x } b1 = \frac{\sqrt{-\ln(0.5)}}{spread}$$

4. Find weight and bias layers, $w2_k$ and $b2_k$, in each $k = 1,2, \dots, S$

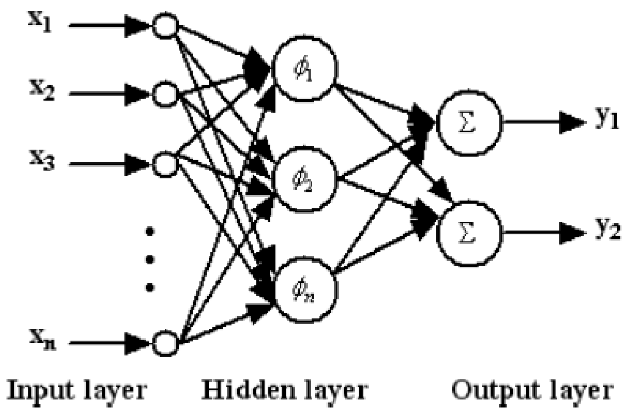


Figure 1: The RBFNN architecture (Wu-Yu & Yu, 2012)

Learning Motivation

Motivation, the powerful force behind our behavior, takes place in every field of our live including in learning (Aslan & Kirikkanat, 2013). Learning motivation can be understood as the extent to which persistent effort a student pays toward learning (Law, Lee, & Yu, 2010). What motivates learners to engage in the cognitive processes of selecting, organizing, and integrating are required for meaningful learning (Mayer, 2014).

When speaking of learning motivation it should describe mechanisms that direct toward the learning goals, initiate learning activity and hold one‘s learning ability on a level that enables person to attain new information and more complex knowledge (Kovacevic, Minovic, Milovanovic, de Pablos, & Starcevic, 2013). They further suggest that context, or a form of presenting a material and learning process itself, are important when comes to the question of learning effectiveness and achievement.

Experts have divided motivation into two major groups of internal motivation and external motivation (Amrai, Motlagh, Zalani, & Parhon, 2011) (Amrai et al., 2011). Intrinsic motivation is motivation in which the task is enjoyable or satisfying in itself; extrinsic motivation is motivation induced by rewards or punishments dependent upon success or failure in the task (Lina, McKeachie, & Kim, 2003). They suggest that, in college classes, grades are clearly an extrinsic reward; intrinsic motivation involves interest in the subject matter, enjoyment of challenge, or a sense of making progress and increasing mastery.

Motivation is an important factor that increases students' achievement (Tuysuz, Yildiran, & Demirci, 2010). Previous studies have identified that there is a significant relationship between learning motivation and students' achievement (Amrai et al., 2011; Bruinsma, 2004). Some of studies also showed that learning motivation can predict students' achievement (Choi & Kim, 2013; Moenikia & Zahed-Babelan, 2010; Steinmayr & Spinath, 2009). (Hamjah, Ismail, Rasit, & Rozali, 2011) suggest that the methods that could be implemented to improve learning motivation students are enhancement of the identified contributing factors namely the students' personality development, lecturers' career awareness, choice of peers, students' spiritual connection with God, family's encouragement, students' financial aid and learning facilities at university.

METHOD AND SAMPLING

The study employed the questionnaire with five point Likert-scales to obtain the data about learning motivation. To gain the data of students' achievement, the GPA data was used. The GPA data were gathered from the academic unit of Islamic University, Bengkulu. The data were collected from 2005-2013. A total of 108 students from mathematics department in Islamic University, Bengkulu were chosen as sample. The data of learning motivation and students' achievement (GPA) can be seen in Appendix A. The data was then analyzed using Statistical Package for Social Sciences (SPSS) version 16.0 and MATLAB R2012a. The simple linear regression analysis and RBFNN were engaged.

FINDINGS AND DISCUSSIONS

Analysis using Simple Linear Regression Method

Before running simple linear regression analysis, there are assumptions should be fulfilled. First, the normality of the data must be fulfilled. The skewness and kurtosis of GPA were 0.162 and -0.125 respectively while the skewness and kurtosis of learning motivation were -0.147 and -0.275. The measures of skewness and kurtosis of the variables were close to 0. It means that the distribution of GPA and learning motivation were considered normally distributed. Beside the data of dependent variable is normally distributed, normality of the residuals for the dependent variable (the differences between calculated and observed scores) must be met in regression analysis. In this case, residuals for GPA scores should be approximately normally distributed. To determine the normality of residual mathematics anxiety scores, Kolmogorov-Smirnov test was used. The result showed that the Sig. Value was 0.143, more than 0.05. It means that the residual for GPA scores is normally distributed. Therefore, the normality of the residual for dependent variable is fulfilled.

The next assumption must be met in regression analysis is multicollinearity. To determine the multicollinearity, Tolerance and Variance Inflation Factor (VIF) value in SPSS output were used. Tolerance value of learning motivation was 1.0 which is not less than 0.1. In addition, the VIF value of learning motivation was 1.0 which is less than 10. It means that there is no multicollinearity between them. In other words, the assumption of multicollinearity is fulfilled.

To determine linearity and outliers, the scatterplot between standardized residual value and standardized prediction value of GPA can be used. Based on Figure 1, the scatterplot does not make a pattern so the model is considered linear. ***In addition, there were no standardized residuals that more than 3.3 or less than -3.3. Therefore, there were no outliers in the data so the assumption for outliers is fulfilled. Because of the assumptions were fulfilled, the regression analysis can be run.***

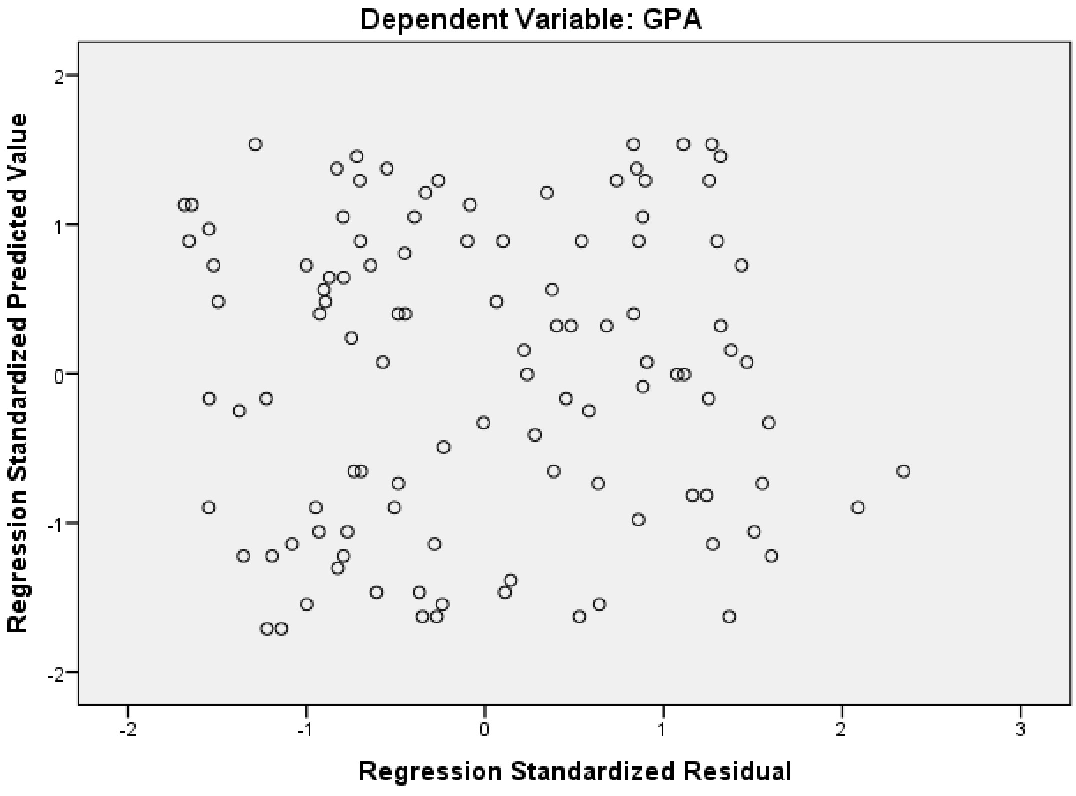


Figure 2: Scatterplot between Standardized Residual Value and Standardized Prediction Value of GPA

The result of the simple linear regression analysis can be seen in Table 1.

Table 1: The Result of Simple Linear Regression Analysis

	Model	Sum of Squares	df	Mean Square	F	Sig.
1	Regression	.076	1	**.076**	1.210	.274[a]
	Residual	6.641	106	.063		
	Total	6.717	107			

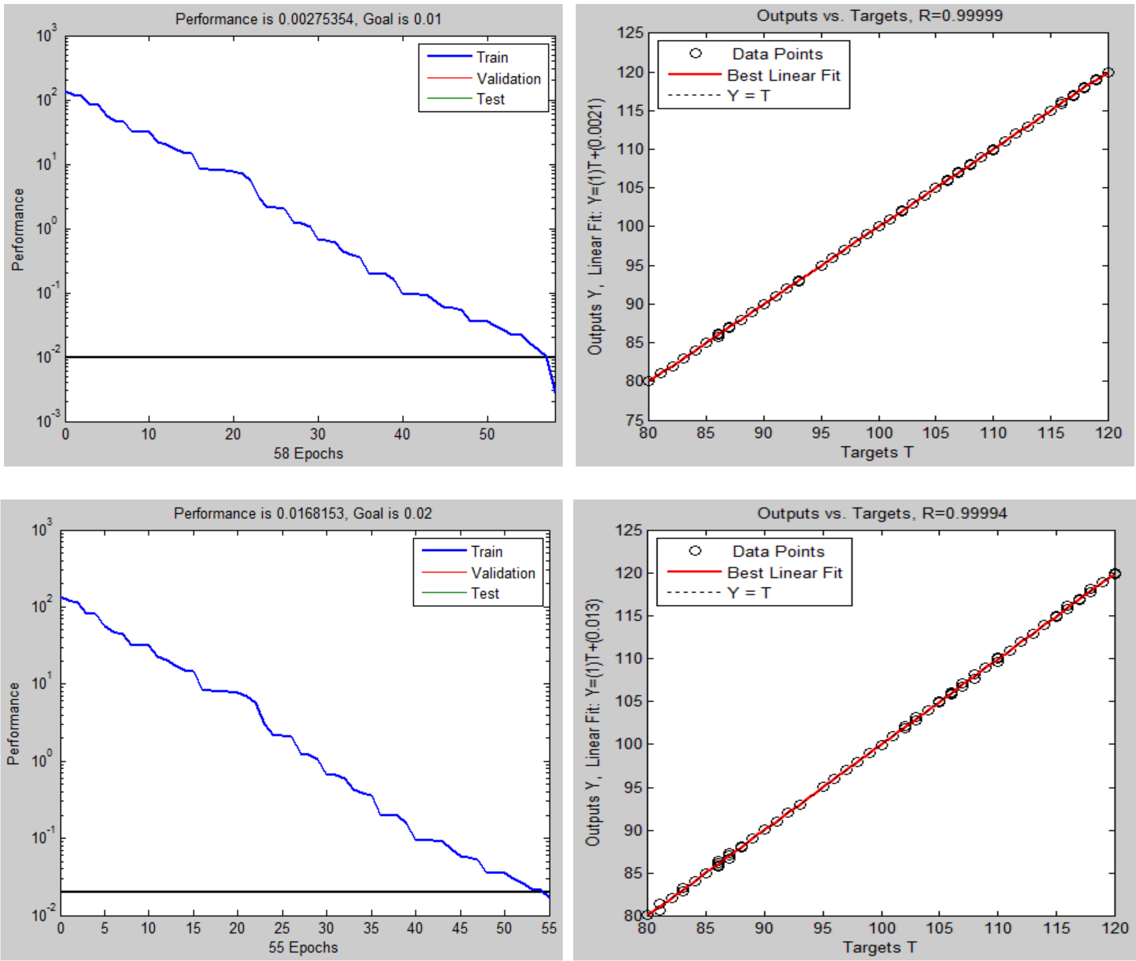
a. Predictors: (Constant), Motivation_X

b. Dependent Variable: GPA_Y

Analysis using RBF Technique

In the second analysis, student achievement data were tested using RBFNN technique. Based on ANNs rules, the data were divided into training and testing data. The training data were selected from 2005 to 2011 or contained 84 data points and 2012-2013 or 24 data points were used as testing data.

Creating a precise neural network by $newrb(P, T, error\_goal, spread)$ function, which is this function creates RBFNN structure, automatically selected the number of hidden layer and made the error to 0. For the sum-square error (SSE) goal values are 0.01, 0.02, and 0.03. Spread is the density of basis function, then spread value of 1 was settled.



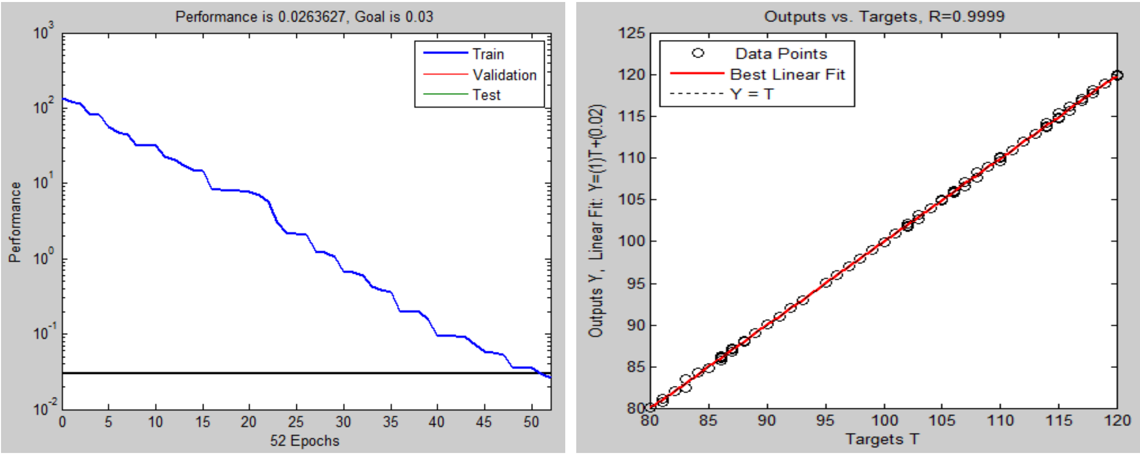


Figure 3: The RBFNN results with SSE 0.01, 0.02, and 0.03

CONCLUSION AND FUTURE WORK

In this paper, the analysis using statistical and AI methods to achieve the model of students' achievement have been conducted in the Islamic University, Bengkulu. According to Figure 3, the results of linear regression analysis show that MSE value is 0.076 with regression Y = 3.193 + 0.002. In addition, the results of RBFNN shows that for SSE = 0.01 then MSE value is 0.003 with regression Y = (1)T + (0.0021), for SSE = 0.02 then MSE value is 0.016 with regression Y = (1)T + (0.013), and for SSE = 0.03 then MSE value is 0.026 with regression Y = (1)T + (0.02).

Indicator test result of data is the smallest error value, where value indicating an error testing is the best model (Wu-Yu & Yu, 2012). Therefore, the determination of the best model is determined by selecting the smallest value of testing error. Based on the results, RBFNN has the smallest value of testing error. Thus, the test results of RBFNN are considered closer to the actual value. In other words, the RBFNN model illustrates the proposed best model to predict students' achievement.

Table 2: Comparison model simple linear regression and RBFNN

Method	MSE	Model
Linear regression	0.076	Y = 3.193 + 0.002
RBFNN with spread = 1		
SSE goal = 0.01	**0.003**	**Y = (1)T + (0.0021)**
SSE goal = 0.02	0.016	Y = (1)T + (0.013)
SSE goal = 0.03	0.026	Y = (1)T + (0.02)

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Appendix A: Data Sample of GPA and Learning Motivation

Year	GPA	Learning Motivation (LM)	Year	GPA	Learning Motivation (LM)	Year	GPA	Learning Motivation (LM)
2005	3.22	83	2008	3.76	88	2011	3.78	102
	3.80	97		3.10	99		3.68	101
	3.30	106		3.41	112		3.21	93
	3.02	115		3.53	116		3.02	112
	3.76	112		3.78	92		3.19	106
	3.55	92		3.20	107		3.44	107
	3.49	93		3.57	112		3.47	101
	3.41	84		3.67	117		3.69	101
	3.15	88		3.08	86		3.05	107
	3.66	120		3.18	86		3.15	90
	3.50	81		3.24	114		3.66	114
	3.47	103		3.78	119		3.42	115
2006	3.27	119	2009	3.71	81	2012	3.55	98
	3.27	102		3.32	111		3.00	90
	3.72	99		3.18	110		3.66	118
	3.52	99		3.64	102		3.31	82
	3.26	112		3.60	89		3.38	117
	3.76	103		3.08	80		3.27	117
	3.63	106		3.68	91		3.28	81
	3.77	120		3.75	105		3.19	88
	3.63	117		3.52	105		3.23	109
	3.02	99		3.53	82		3.40	83
	3.04	86		3.31	118		3.70	91
	3.52	108		3.21	109		3.30	81
2007	3.46	112	2010	3.36	116	2013	3.54	105
	3.24	118		3.28	83		3.76	117
	3.27	110		3.63	100		3.12	82
	3.23	104		3.17	85		3.06	80
	3.70	87		3.11	87		3.65	112
	3.31	87		3.34	114		3.59	105
	3.06	98		3.78	86		3.79	110
	3.31	106		3.40	97		3.98	93
	3.05	110		3.34	95		3.26	90
	3.22	93		3.03	115		3.73	120
	3.13	120		3.20	108		3.27	92
	3.47	96		3.05	113		3.91	90

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