DEVELOPMENT OF GROWTH MODELS FOR ELECTRONICS HARDWARE AND SOFTWARE COMPONENTS

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ABSTRACT

Now a days information technology plays an important role in all fields of sciences, arts and commerce, management and medicine. Up to date information on each and every topic is utilized everybody in all fields through internet. India is investing money in crores in production of software and hardware. Forecast is playing an important role in future prediction. In this paper we develop the growth models for electronic hardware and software components. Suitable Polynomial equations with time ‘t’ (independent variable) and time series value ‘y_i’ (dependent variable) for software production, hardware production and total production are fitted. Coefficient of determination (R^2) measures the percentage variation in the dependent variable, that is accounted by the independent variable.

KEYWORDS
Forecast, Growth models, Software, Hardware & Coefficient of determination.

1. INTRODUCTION

A comparative study of challenges in integrating open source software and inner source software by klaas-jan Stol et al[1], in their paper has an objective to shed light on challenges related to building products with components that have been developed within an inner source development environment. They followed an initial systematic literature review to generate seed category data constructs, and performed an in-depth exploratory case study in an organization that has a significant track record in the implementation of inner source. Data was gathered through semi structured interviews with participants from a range of divisions across the organization. Interviews were transcribed and analyzed using qualitative data analysis techniques.

Reza Meimandi parizi et al [2] studied on “empirical evaluation of the fault detection effectiveness and test effort efficiency of the automated AOP (aspect-oriented programming) testing approaches”. In their paper using mutation analysis and examined four existing automated AOP testing approaches i.e. Wrasp [3], Aspectra [4], Raspect [5] and EAT [6]. P.Hu et al [7] studied about “An empirical comparison between direct and indirect test results checking approaches”. An empirical study of the robustness of windows NT applications using random testing was done by J.E. Forrester et al [8].

Now a days forecasting plays an important role not only in weather conditions, but also to the business, economics and so many other fields. Forecasting is important to planning better future. In this paper we are fitted a Polynomial equation for forecasting production of Electronics and IT in India.

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2. METHODOLOGY

In this paper our main objective is to forecasts how many crores that India’s future production in hardware, software and total. Before going production to forecast, we have to fit the suitable and appropriate models for the above three variables. Models are tested using coefficient of determination i.e., “R$^2$” criterion. The data how we are using the forecasts in time series data. If our data looks as follows:

$$t_i : t_1 \quad t_2 \quad \ldots \ldots \quad t_n$$

$$y_i : y_1 \quad y_2 \quad \ldots \ldots \quad y_n$$

Here \( t \) is time (independent variable) and \( y \) is time series value.

The suitable equation, dependent variable fitted for the given data is

$$y_i = A t_i^3 + B t_i^2 + C t_i + D$$

i.e. 3 degree polynomial for time ‘\( t_i \)’. The above equation tells about the values of time series value ‘\( y_i \)’ according to change in time ‘\( t_i \)’.

If A, B, C and D are constants estimated by the Principle of least squares and the fitted equation is

$$\hat{y}_i = \hat{A} t_i^3 + \hat{B} t_i^2 + \hat{C} t_i + \hat{D}$$

Difference between the actual time series value and estimated time series value is the error.

$$y_i - \hat{y}_i = y_i - (\hat{A} t_i^3 - \hat{B} t_i^2 - \hat{C} t_i - \hat{D})$$

Error sum of square is obtained by squaring the error values and then total all the squares,

$$S = \sum_{i=1}^{n} (y_i - \hat{A} t_i^3 - \hat{B} t_i^2 - \hat{C} t_i - \hat{D})^2$$

To minimize ‘S’, eq. (2) is partially differentiated with respect to A, B, C, D and we equate all its derivatives to zero, and we get four normal equations as follows:

Differenite the equation (2) with respect to \( A \) and equate it to zero, then we get

$$\sum_{i=1}^{n} y_i t_i^3 - \hat{A} \sum_{i=1}^{n} t_i^6 - \hat{B} \sum_{i=1}^{n} t_i^5 - \hat{C} \sum_{i=1}^{n} t_i^4 - \hat{D} \sum_{i=1}^{n} t_i^3 = 0$$

Differenite the equation (2) with respect to \( B \) and equate it to zero, we get

$$\sum_{i=1}^{n} y_i t_i^2 - \hat{A} \sum_{i=1}^{n} t_i^5 - \hat{B} \sum_{i=1}^{n} t_i^4 - \hat{C} \sum_{i=1}^{n} t_i^3 - \hat{D} \sum_{i=1}^{n} t_i^2 = 0$$

Differenite the equation (2) with respect to \( C \) and equate it to zero, we get

$$\sum_{i=1}^{n} y_i t_i - \hat{A} \sum_{i=1}^{n} t_i^4 - \hat{B} \sum_{i=1}^{n} t_i^3 - \hat{C} \sum_{i=1}^{n} t_i^2 - \hat{D} \sum_{i=1}^{n} t_i = 0$$

Differenite the equation (2) with respect to \( D \) and equate it to zero, we get

$$\sum_{i=1}^{n} y_i - \hat{A} \sum_{i=1}^{n} t_i^3 - \hat{B} \sum_{i=1}^{n} t_i^2 - \hat{C} \sum_{i=1}^{n} t_i - \hat{D} \sum_{i=1}^{n} t_i = 0$$
\[
\sum_{i=1}^{n} y_i t_i^2 - \hat{A} \sum_{i=1}^{n} t_i^3 - \hat{B} \sum_{i=1}^{n} t_i^4 - \hat{C} \sum_{i=1}^{n} t_i^5 - \hat{D} \sum_{i=1}^{n} t_i^6 = 0
\]
\[
\sum_{i=1}^{n} y_i t_i^2 = \hat{A} \sum_{i=1}^{n} t_i^3 + \hat{B} \sum_{i=1}^{n} t_i^4 + \hat{C} \sum_{i=1}^{n} t_i^5 + \hat{D} \sum_{i=1}^{n} t_i^6
\]  
---------(4)

Differentiate the equation (2) with respect to \( C \) and equate it to zero, we get
\[
\frac{\partial S}{\partial C} = \frac{\partial}{\partial C} \sum_{i=1}^{n} \left( y_i - \hat{A} t_i^3 - \hat{B} t_i^2 - \hat{C} t_i - \hat{D} \right)^2
\]
\[
= 2 \sum_{i=1}^{n} \left( y_i - \hat{A} t_i^3 - \hat{B} t_i^2 - \hat{C} t_i - \hat{D} \right) \cdot (-t_i) = 0
\]
\[
\sum_{i=1}^{n} y_i t_i = \hat{A} \sum_{i=1}^{n} t_i^4 + \hat{B} \sum_{i=1}^{n} t_i^3 + \hat{C} \sum_{i=1}^{n} t_i^2 + \hat{D} \sum_{i=1}^{n} t_i
\]  
---------(5)

Differentiate the equation (2) with respect to \( D \) and equate it to zero, we get
\[
\frac{\partial S}{\partial D} = \frac{\partial}{\partial D} \sum_{i=1}^{n} \left( y_i - \hat{A} t_i^3 - \hat{B} t_i^2 - \hat{C} t_i - \hat{D} \right)^2
\]
\[
= 2 \sum_{i=1}^{n} \left( y_i - \hat{A} t_i^3 - \hat{B} t_i^2 - \hat{C} t_i - \hat{D} \right) \cdot (-1) = 0
\]
\[
\sum_{i=1}^{n} y_i - \hat{A} \sum_{i=1}^{n} t_i^3 - \hat{B} \sum_{i=1}^{n} t_i^2 - \hat{C} \sum_{i=1}^{n} t_i - \hat{D} \sum_{i=1}^{n} 1 = 0
\]
\[
\sum_{i=1}^{n} y_i t_i = \hat{A} \sum_{i=1}^{n} t_i^4 + \hat{B} \sum_{i=1}^{n} t_i^3 + \hat{C} \sum_{i=1}^{n} t_i^2 + \hat{D} \sum_{i=1}^{n} t_i - n \hat{D} = 0
\]
\[
\sum_{i=1}^{n} y_i = \hat{A} \sum_{i=1}^{n} t_i^4 + \hat{B} \sum_{i=1}^{n} t_i^3 + \hat{C} \sum_{i=1}^{n} t_i^2 + \hat{D} \sum_{i=1}^{n} t_i + n \hat{D}
\]  
---------(6)

By solving the above four normal equations (3), (4), (5) and (6), we obtain the constants \( A, B, C \) and \( D \).

By change time \( t_i \) to \( T_i \), by changing origin and scale equations, \( \sum_{i=1}^{n} T_i = 0 \), \( \sum_{i=1}^{n} T_i^1 = 0 \) and \( \sum_{i=1}^{n} T_i^3 = 0 \) and the normal equations becomes
\[
\sum_{i=1}^{n} y_i T_i = \hat{A} \sum_{i=1}^{n} T_i^6 + \hat{C} \sum_{i=1}^{n} T_i^4
\]  
---------(7)
\[
\sum_{i=1}^{n} y_i T_i^2 = \hat{B} \sum_{i=1}^{n} T_i^4 + \hat{D} \sum_{i=1}^{n} T_i^2
\]  
---------(8)
\[
\sum_{i=1}^{n} y_i T_i = \hat{A} \sum_{i=1}^{n} T_i^4 + \hat{C} \sum_{i=1}^{n} T_i^2
\]  
---------(9)
\[
\sum_{i=1}^{n} y_i T_i = \hat{B} \sum_{i=1}^{n} T_i^2 + n \hat{D}
\]  
---------(10)

By solving equations (7) and (9), we get constant \( \hat{A} \) and \( \hat{C} \).

Multiply eq. (7) with \( \sum_{i=1}^{n} T_i^4 \), we get
\[
\sum_{i=1}^{n} T_i^4
\]
\[ \sum_{i=1}^{n} y_i T_i^3 = \hat{A} \sum_{i=1}^{n} T_i^4 + \hat{C} \left( \sum_{i=1}^{n} T_i^4 \right)^2 \]\\
\text{------ (11)}

Subtracting equation (9) from (11), we get

\[ \sum_{i=1}^{n} y_i T_i^3 - \sum_{i=1}^{n} y_i T_i = \hat{C} \left[ \left( \sum_{i=1}^{n} T_i^4 \right)^2 - \sum_{i=1}^{n} T_i^2 \right] \]

\[ \hat{C} = \frac{\sum_{i=1}^{n} y_i T_i^3 - \sum_{i=1}^{n} y_i T_i}{\sum_{i=1}^{n} T_i^4} \]\\
\text{------ (12)}

Substituting \( \hat{C} \) value in equation (9), we get \( \hat{A} \)

\[ \sum_{i=1}^{n} y_i T_i = \hat{A} \sum_{i=1}^{n} T_i^4 + \frac{\sum_{i=1}^{n} T_i^4}{\sum_{i=1}^{n} T_i^4} - \sum_{i=1}^{n} y_i T_i \]

\[ \sum_{i=1}^{n} y_i T_i - \sum_{i=1}^{n} y_i T_i = \hat{A} \sum_{i=1}^{n} T_i^4 = N_1 \]\\
\text{------ (13)}

\[ D_1 = \sum_{i=1}^{n} T_i^4 \]\\
\text{------ (14)}

Equation (14) in (13), we get

\[ N_1 = \hat{A} D_1 \]
Solving equations (8) and (10), we obtain \( \hat{B} \) and \( \hat{C} \).

Multiply eq. (10) with \( \frac{1}{n} \) then we get,

\[
\sum_{i=1}^{n} y_i T_i = \hat{B} \left( \frac{\sum_{i=1}^{n} T_i^2}{n} \right) + \sum_{i=1}^{n} T_i^2 \hat{D}
\]

Subtracting equation (8) from equation (15), we get

\[
\sum_{i=1}^{n} y_i T_i = \hat{B} \left( \frac{\sum_{i=1}^{n} T_i^2}{n} \right) + \sum_{i=1}^{n} T_i^2 \hat{D} - \sum_{i=1}^{n} y_i T_i^2
\]

Substituting equation (16) in equation (10), we get

\[
\sum_{i=1}^{n} y_i T_i = \frac{\sum_{i=1}^{n} y_i T_i}{n} - \sum_{i=1}^{n} y_i T_i^2 = \hat{B} \left( \frac{\sum_{i=1}^{n} T_i^2}{n} \right) - \sum_{i=1}^{n} T_i^4
\]

The fitted polynomial equation is

\[
\hat{y} = \hat{A} T^3 + \hat{B} T^2 + \hat{C} T + D
\]

2.1. Coefficient of determination (R²)

Correlation coefficient between two variables measures the linear relationship between them and indicates the amount of variation of one variable which is associated with or is accounted for by another variable. Square of correlation coefficient is coefficient of determination R². In other words the coefficient of determination gives the percentage variation in the dependent variable that is accounted for by the independent variable. Coefficient of determination gives the ratio of the explained variance to total variance.
2.2. Empirical investigations

A suitable and appropriate model fitted to time series data of software, hardware and total production by India. The appropriate model for three time series data is

\[
\hat{y} = A t_i^3 + B t_i^2 + C t_i + D
\]

where \( t_i \) is Time at \( i^{th} \) time period

\( y_i \) is Time series value at \( i^{th} \) time period

A, B, C and D are constants

The above equation is the third degree polynomial growth equation.

Electronics production data (hardware and software) in each year is given in Table-1[9]. The hardware includes consumer electronics, industrial electronics, computer hardware, communication and broadcast equipment, strategic electronics and electronic components. Software includes software for exports and domestic software, total production is both hardware and software.

Table 1

<table>
<thead>
<tr>
<th>Time</th>
<th>Software</th>
<th>Hardware</th>
<th>Total production</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>27750</td>
<td>23000</td>
<td>50750</td>
</tr>
<tr>
<td>2000</td>
<td>30880</td>
<td>35800</td>
<td>66680</td>
</tr>
<tr>
<td>2001</td>
<td>32150</td>
<td>44600</td>
<td>76750</td>
</tr>
<tr>
<td>2002</td>
<td>36800</td>
<td>56000</td>
<td>92800</td>
</tr>
<tr>
<td>2003</td>
<td>42700</td>
<td>70500</td>
<td>113200</td>
</tr>
<tr>
<td>2004</td>
<td>49800</td>
<td>95500</td>
<td>145300</td>
</tr>
<tr>
<td>2005</td>
<td>54500</td>
<td>124000</td>
<td>178500</td>
</tr>
<tr>
<td>2006</td>
<td>64400</td>
<td>167175</td>
<td>231575</td>
</tr>
<tr>
<td>2007</td>
<td>79800</td>
<td>203060</td>
<td>282860</td>
</tr>
<tr>
<td>2008</td>
<td>94060</td>
<td>259260</td>
<td>353300</td>
</tr>
<tr>
<td>2009</td>
<td>107370</td>
<td>297400</td>
<td>404770</td>
</tr>
</tbody>
</table>

2.3. Software production

The fitted equation for the software production data is

\[
y = 31.31 T^3 + 234 T^2 + 1076 T + 26754
\]

Coefficient of determination \( R^2 \) is 0.997 i.e. 99.7% of the time series value \( y \) and has been explained by the time ‘t’ and the remaining 0.3% of the variation is due to other factors.

2.4. Hardware production

The fitted equation for the hardware export data is

\[
y = 19.24 T^3 + 2315 T^2 - 2782 T + 27665
\]

Coefficient of determination \( R^2 \) is 0.997 i.e. 99.7% of time series value \( y \) and has been explained by the time ‘t’ and the remaining 0.3% of the variation is due to other factors.

2.5. Total production

The fitted equation for the total production data is

\[
y = 50.59 T^3 + 2549 T^2 - 1702 T + 54415
\]
Coefficient of determination \( R^2 \) is 0.998 i.e. 99.8% of time series values (\( y \)) and has been explained by the time ‘\( t \)’ and the remaining 0.2% of the variation is due to other factors.

Plots are drawn by taking time ‘\( t \)’ on x-axis and time series value ‘\( y \)’ on y-axis for software production using equation (18), hardware production using equation (19) and total production using equation (20). The corresponding curves are shown in Figure 1, Figure 2 and Figure 3 respectively for both actual data and forecast data. The curves for original time series values and forecast time series values are coincide.

![Figure 1. Software Production for actual data and forecast data.](image1)

![Figure 2. Hardware Production for actual data and forecast data.](image2)

Table -2 contains 4 columns, first column tells about the time ‘\( t \)’ in years, second column tells about percentage growth of software exports, third and fourth columns gives the information regarding the percentage growth of hardware and total exports.
Figure 3. Total Production for actual data and forecast data.

<table>
<thead>
<tr>
<th>Time</th>
<th>Software</th>
<th>Hardware</th>
<th>Total</th>
</tr>
</thead>
<tbody>
<tr>
<td>1999</td>
<td>-----</td>
<td>-----</td>
<td>-----</td>
</tr>
<tr>
<td>2000</td>
<td>0.112793</td>
<td>0.56</td>
<td>0.31</td>
</tr>
<tr>
<td>2001</td>
<td>0.04</td>
<td>0.24</td>
<td>0.15</td>
</tr>
<tr>
<td>2002</td>
<td>0.15</td>
<td>0.25</td>
<td>0.21</td>
</tr>
<tr>
<td>2003</td>
<td>0.16</td>
<td>0.26</td>
<td>0.22</td>
</tr>
<tr>
<td>2004</td>
<td>0.16</td>
<td>0.35</td>
<td>0.28</td>
</tr>
<tr>
<td>2005</td>
<td>0.10</td>
<td>0.30</td>
<td>0.23</td>
</tr>
<tr>
<td>2006</td>
<td>0.18</td>
<td>0.25</td>
<td>0.30</td>
</tr>
<tr>
<td>2007</td>
<td>0.24</td>
<td>0.25</td>
<td>0.22</td>
</tr>
<tr>
<td>2008</td>
<td>0.18</td>
<td>0.28</td>
<td>0.25</td>
</tr>
<tr>
<td>2009</td>
<td>0.14</td>
<td>0.15</td>
<td>0.16</td>
</tr>
<tr>
<td>Average</td>
<td>0.15</td>
<td>0.30</td>
<td>0.23</td>
</tr>
</tbody>
</table>

Table-3 gives the information for the production, fitted polynomial equation, coefficient of determination and average growth rate per year.

<table>
<thead>
<tr>
<th>Type of production</th>
<th>Fitted Polynomial Equation</th>
<th>Coefficient of Determination ($R^2$)</th>
<th>Average growth rate per Annum</th>
</tr>
</thead>
<tbody>
<tr>
<td>Software</td>
<td>$31.31 T^3 + 234 T^2 + 1076 T + 26754$</td>
<td>0.997</td>
<td>15%</td>
</tr>
<tr>
<td>Hardware</td>
<td>$19.24 T^3 + 2315 T^2 - 2782 T + 27665$</td>
<td>0.997</td>
<td>30%</td>
</tr>
<tr>
<td>Total</td>
<td>$50.59 T^3 + 2549 T^2 - 1702 T + 54415$</td>
<td>0.998</td>
<td>23%</td>
</tr>
</tbody>
</table>

On an average 15% growth rate is recorded for software, 30% growth rate for hardware and 23% growth rate for total exports.

3. CONCLUSIONS

The growth models for hardware, software and total production are developed. The fitted equation (18) for software exports of India with coefficient of determination ($R^2$) is 0.997 and average growth rate per annum is 15 percent. The fitted equation (19) for hardware exports of
India with coefficient of determination ($R^2$) is 0.997 and 33 percent of average growth rate is showing per annum. The fitted equation (20) for total exports in India with coefficient of determination ($R^2$) is 0.998 and 23 percent growth is observed on an average per annum.

REFERENCES


Authors

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