An Analysis of Computer Processing Speed Since 1993

Mike Schumacher

A World View of Mathematics and Data Analysis

by

Dr. John R. Taylor, Mrs. Desiré J. Taylor

and Mrs. Christina L. Turner

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Abstract

The purpose of this study was to see if computer processor clock speed increased over time, what trend it would follow, and if it could be used to accurately predict a data sample outside the collected data set. The data was collected from the Intel website, and organized into an excel spreadsheet. After organizing the data into several scatter plots, trend lines were calculated. It was found that most computer types followed an exponential trend, but a few rose and then fell in a polynomial trend. These trends were all hypothesis tested, and found to be statistically proven. Upon testing data points outside the data set, however, it was found to be moderately inaccurate. From the data we can conclude that computer processor speeds rose over time, except for the few that followed the polynomial trend. These few may have been affected by the introduction of multi-core processors, which allow increases in performance without having as high a clock speed. Further research should be done on the relationships between computer clock speed and the number of cores, and this study could be repeated again in the future to see if this trend continues or if other types are affected by it.

Background and Research Question

The computer clock rate measures how quickly it executes its instruction sets. Simpler instructions sets take less time to execute, and more complicated instruction set more (Dictionary.com). The Intel 4004 was created in November, 1971 and was the world's first single chip microprocessor. It was the start of a revolution in computing, and was the first universal processor (Bellis). Later, Intel created many more processors and is still a leading producer today. The original 4004 ran at a clock rate of 108 KHz (108,000 cycles/second). Today's computers run in the gigahertz range, or billions of cycles per second. Today's computers have also begun to diversify, with desktop computers for the standard user, mobile computers like laptops and notebooks, server and business computers to distribute data to a whole network, gaming and computer enthusiast computers for the high powered applications, and value computers using cheaper hardware at lower speeds. At around 2005, manufacturers began to make multi-core processors, which have 2 or more processor on the same port. This does not multiply the speed by the number of cores on the processor, but it does allow for performance boosts (Search Data Center). The question to be tested about computer clock rates was whether clock rates of processors increased over time, what type of trend it would increase at, how accurate these trend lines were, and how accurately it could be predicted for a known processor speed outside the collected data range.

Methods

The data on computer processor speed was collected directly from the Intel website. The clock speed of the processors, their release date, and their intended purpose was recorded. The samples were organized and processor speeds for the same purpose and released in the same month were averaged to compensate for the fact that often lower- and higher- end processors are released at differing prices. It was then placed on separate scatter plots of desktop computers, mobile computers, business and server computers, gaming and computer enthusiast computers, value computers, and an overall category. Microsoft Excel was used to calculate exponential and polynomial trend lines along with their R and R^2 values and the most correlated line was chosen to represent the data. The trend lines were first hypothesis tested for their correlation. The hypothesis test began with the creation of the null and alternate hypothesis, or the H_0 and the H_a. Then the T-score was calculated, by the following formula:

$$\frac{\quad}{\quad}$$

The alpha level of .005, which is the probability of making the error of rejecting your null hypothesis when it was actually true, was chosen and referenced on the t-chart. Then the rejection region was drawn and a conclusion was reached about the accuracy of each trend line. The trend lines were then tested on accuracy by comparing their predictions for a date in the future with those of known processor speeds. Five processors were tested on both the overall and their type trends.

Results and Discussion

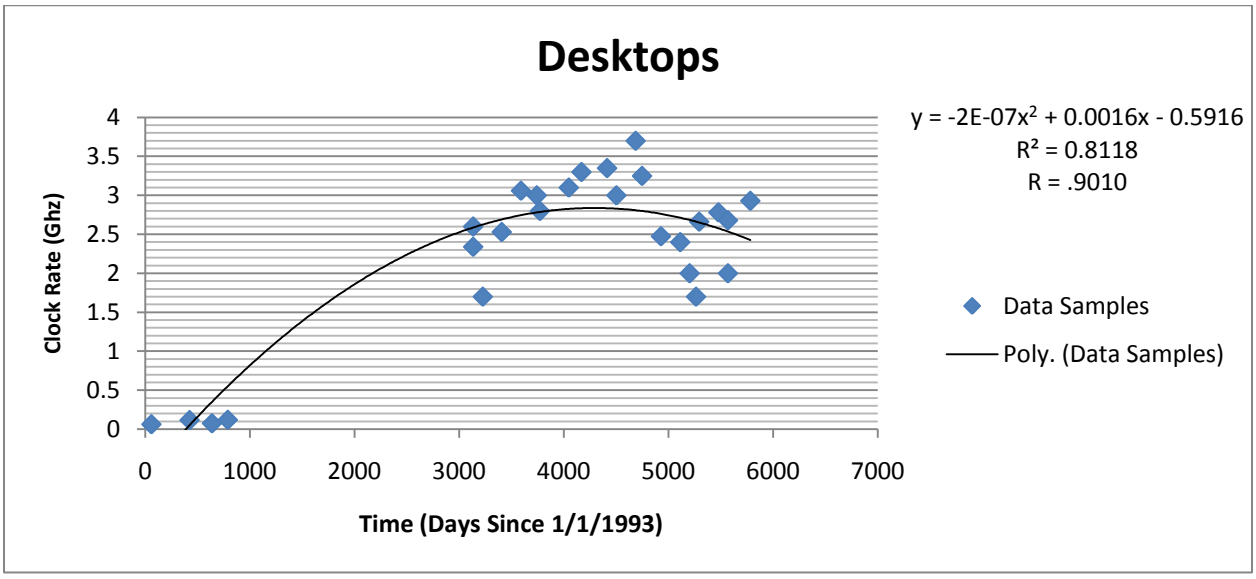

Fig. 1

This is an analysis of desktop computers, and the trend found to be most accurate for desktops was a polynomial trend. The R value is quite high, so the hypothesis test for correlation was found to be well within the rejection region. The polynomial trend rose at first, but then curiously began to fall. The introduction of multi-core processors may have had an effect on the speed.

Hypothesis test:

H_0: $\rho \leq 0$

H_a: $\rho > 0$

Rejection Region: One tailed right test

Alpha level of .005 with 26 samples

= critical value of 2.797

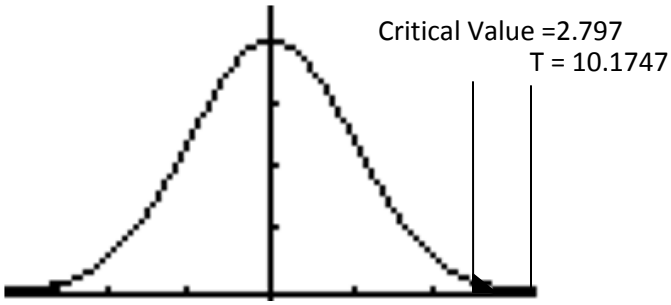

Fig. 2

Decision: Reject H_0

Conclusion: There is sufficient evidence at the alpha level of .005 to conclude that this polynomial trend represents the data.

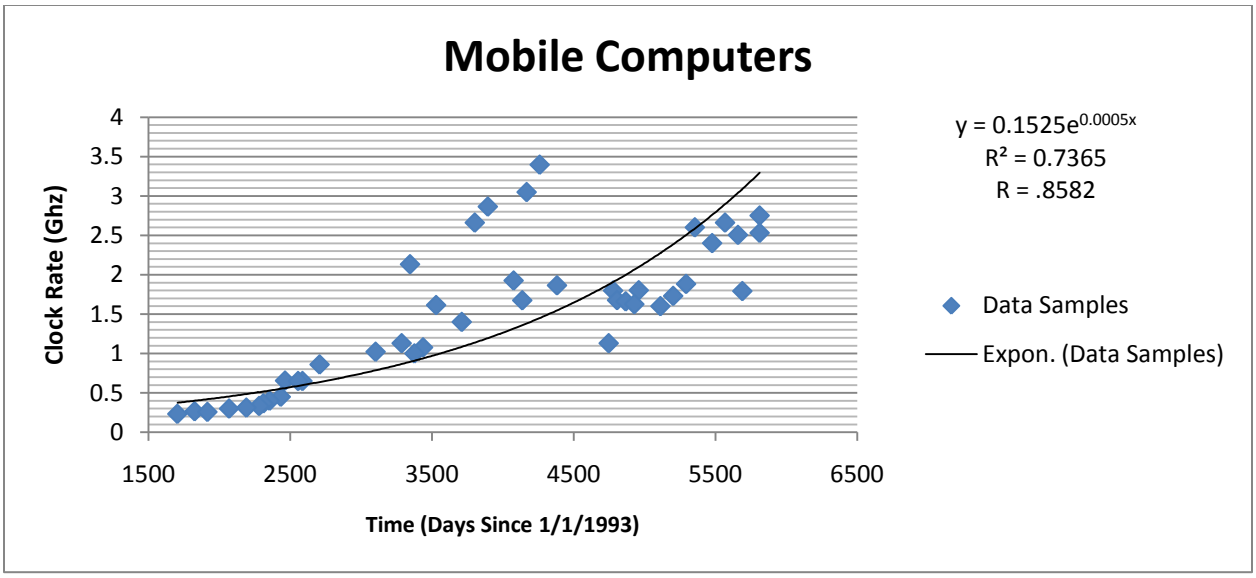

Fig. 3

Mobile computers follow an exponential trend, and again the R value is high, so the hypothesis test for correlation was found to be well within the rejection region. This seems to follow the standard that the speed will increase over time.

Hypothesis test:

H_0: $\rho \leq 0$

H_a: $\rho > 0$

Rejection Region: One tailed right test

Alpha level of .005 with 43 samples

= critical value of 2.576

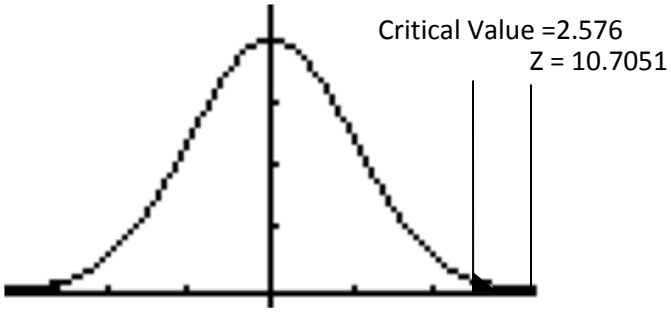

Fig. 4

Decision: Reject H_0

Conclusion: There is sufficient evidence at the alpha level of .005 to conclude that this exponential trend represents the data.

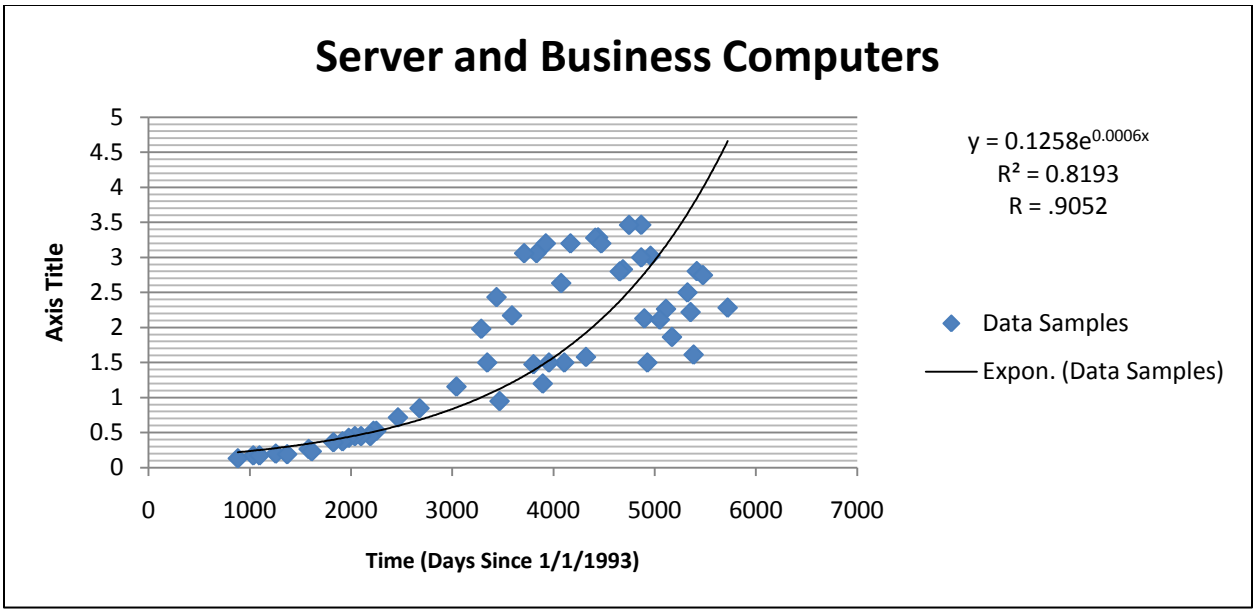

Fig. 5

Server and business computers actually fit the data the best, and the exponential trend had the highest R value, and the hypothesis test for correlation was of course found to be within the rejection region. The exponential trend is also increasing over time, but at a faster rate than the mobile computers.

Hypothesis test:

H_0: $\rho \leq 0$

H_a: $\rho > 0$

Rejection Region: One tailed right test

Alpha level of .005 with 53 samples

= critical value 2.576

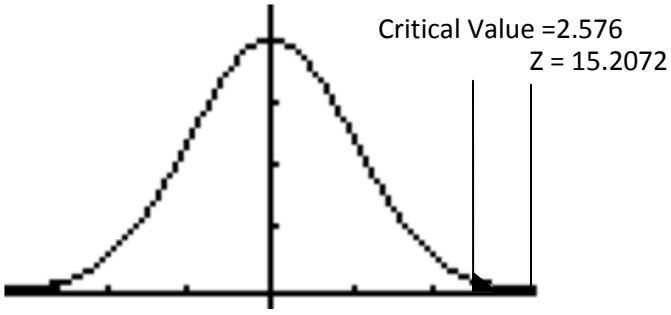

Fig. 6

Decision: Reject H_0

Conclusion: There is sufficient evidence at the alpha level of .005 to conclude that this exponential trend represents the data.

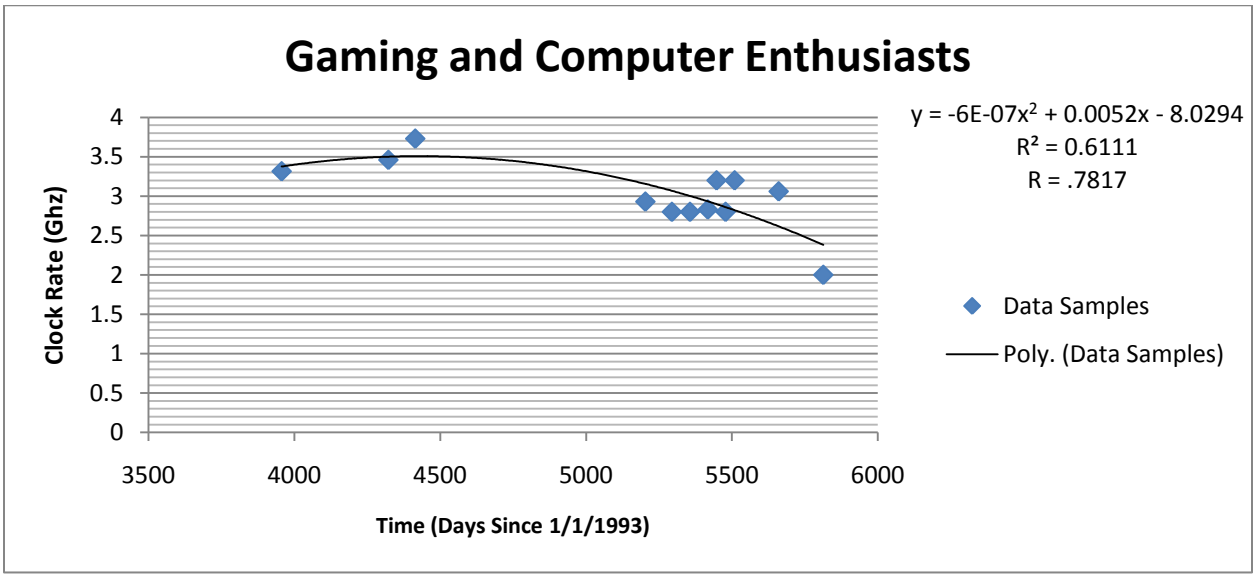

Fig. 7

Like the desktop computers, a polynomial trend was the best fitting. The R value was not as good with this as the other trends, but the hypothesis test for correlation was still found to be within the rejection region. This appears to be rising and falling as well, and may also have been affected by the introduction of multi-core processors.

Hypothesis test:

H_0: $\rho \leq 0$

H_a: $\rho > 0$

Rejection Region: One tailed right test

Alpha level of .005 with 12 samples

= critical value 3.169

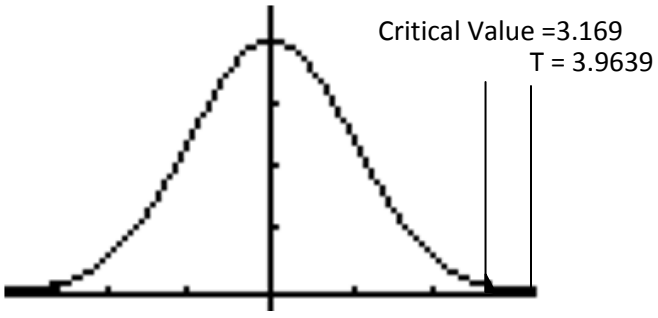

Fig. 8

Decision: Reject H_0

Conclusion: There is sufficient evidence at the alpha level of .005 to conclude that this polynomial trend represents the data.

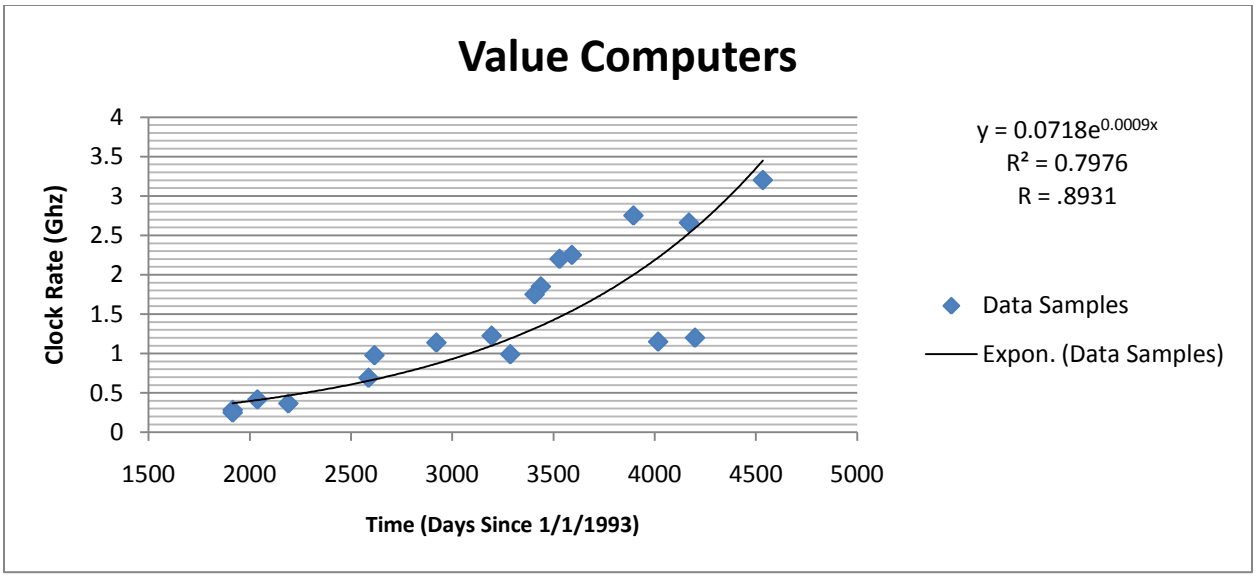

Fig. 9

For value computers the trend most accurate was an exponential trend, and the R value was very good as well. The hypothesis test for correlation was found to be inside the rejection region. This is following the increase over time trend, but at an even faster rate than the server and business computers.

Hypothesis test:

H_0: $\rho \leq 0$

H_a: $\rho > 0$

Rejection Region: One tailed right test

Alpha level of .005 with 18 samples

= critical value 2.9210

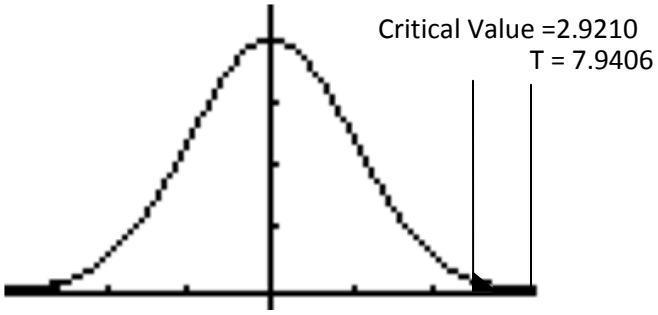

Fig. 10

Decision: Reject H_0

Conclusion: There is sufficient evidence at the alpha level of .005 to conclude that this exponential trend represents the data.

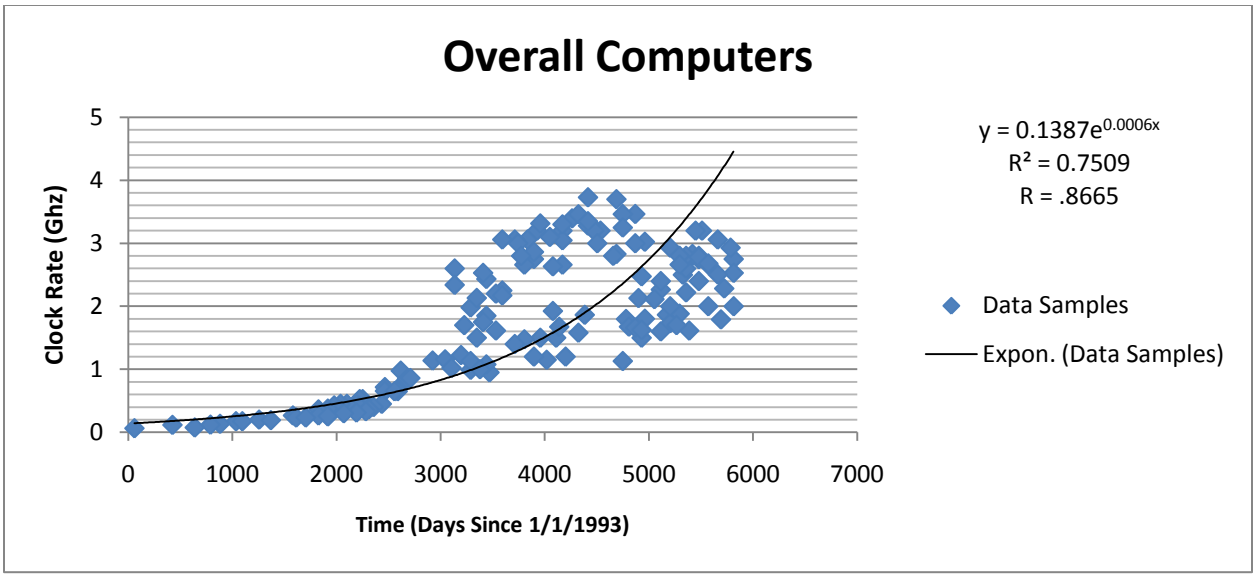

Fig. 11

Overall, computers follow an exponential trend, and the R value was good, so the hypothesis test for correlation was found to be very well within the rejection region. The interesting thing to note is that one can see on the graph when computers started to specify, from very strictly following the line to having a very broad range.

Hypothesis test:

H_0: $\rho \leq 0$

H_a: $\rho > 0$

Rejection Region: One tailed right test

Alpha level of .005 with 153 samples

= critical value 2.576

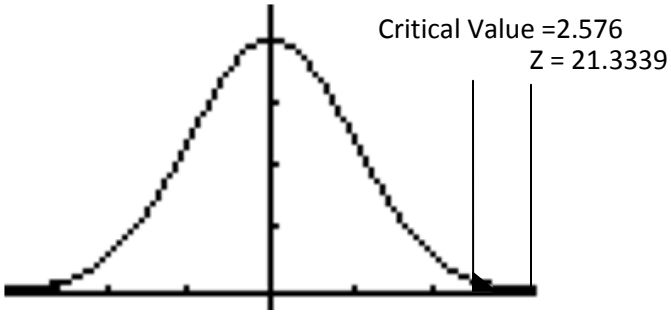

Fig. 12

Decision: Reject H_0

Conclusion: There is sufficient evidence at the alpha level of .005 to conclude that this exponential trend represents the data.

When trying to predict a computer outside the collected data set, the results in table 1 were gathered.

Processor	Type	Actual Speed	Predicted (Type Equation)	Predicted (Overall Equation)
Intel® Core™ i7-860 Processor	Gaming/ Computer Enthusiast	2.80 GHz	1.39 GHz	5.35 GHz
Intel® Core™ i5-750 Processor	Desktop	2.66 GHz	1.74 GHz	5.35 GHz
Intel® Core™ i3-530 Processor	Value	2.93 GHz	19.19 GHz	5.75 GHz
Intel® Xeon® Processor W3550	Business and server	3.06 GHz	4.34 GHz	4.79 GHz
Intel® Core™ i5-430M	Mobile	2.26 GHz	3.40 GHz	5.75 GHz

Table 1

Conclusions

- ### Research Question

The first point of the question, whether computer processing speeds increase over time, was statistically proven to be true in some cases. All but the desktop and gaming and computer enthusiast computers were proven to have an exponential correlation. The desktop and computer enthusiast computers, however, were shown to have a quadratic correlation that rose and then fell. The hypothesis tests for each trend line were positive in proving correlation. Trying to predict data outside of the collected data set was found to be not as accurate. The overall equation was found to be moderately inaccurate, the gaming and computer enthusiast, desktop, business and server, and mobile trends more accurate, and the value computer equation entirely inaccurate. This shows that the data cannot be used to predict future events, and that the trends may be changing.

- Future directions

While most of the data sets showed exponential trends, the desktop and gaming and computer enthusiast computers showed a trend of rising and then falling. This could be due to having more complicated instruction sets, technology beginning to reach its limits, or it could be due to the introduction of multi-core processors. Future studies could look for a relationship between time and number of cores, or between clock rate and the number of cores. The experiment could also be repeated again in the future to see if the trend of falling continues or affects other categories of computers, or if most computer types begin to level off.

References

ARK | Your source for information on Intel® products. *Intel*. Retrieved July 16, 2010, from http://ark.intel.com/Default.aspx

Bellis, M. (n.d.). Intel 4004 - the world's first single Chip microprocessor. *Inventors*. Retrieved July 16, 2010, from http://inventors.about.com/od/mstartinventions/a/microprocessor.htm

Clock rate. (n.d.). *Dictionary.com*. Retrieved July 16, 2010, from dictionary.reference.com/browse/clock+rate

Intel microprocessor quick reference guide - product family. (n.d.). *Laptop, notebook, desktop, server and embedded processor technology - Intel*. Retrieved July 16, 2010, from http://www.intel.com/pressroom/kits/quickreffam.htm#i486

What is multi-core processor?. (n.d.). *Search Data Center*. Retrieved July 16, 2010, from http://searchdatacenter.techtarget.com/sDefinition/0,,sid80_gci1015740,00.html