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Programming language trends : an empirical study

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ABSTRACT

PROGRAMMING LANGUAGE TRENDS: AN EMPIRICAL STUDY

by

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Predicting the evolution of software engineering technology trends is a dubious proposition. The recent evolution of software technology is a prime example; it is fast paced and affected by many factors, which are themselves driven by a wide range of sources. This dissertation is part of a long term project intended to analyze software engineering technology trends and how they evolve. Basically, the following questions will be answered: How to watch, predict, adapt to, and affect software engineering trends?

In this dissertation, one field of software engineering, programming languages, will be discussed. After reviewing the history of a group of programming languages, it shows that two kinds of factors, intrinsic factors and extrinsic factors, could affect the evolution of a programming language. Intrinsic factors are the factors that can be used to describe the general design criteria of programming languages. Extrinsic factors are the factors that are not directly related to the general attributes of programming languages, but still can affect their evolution. In order to describe the relationship of these factors and how they affect programming language trends, these factors need to be quantified. A score has been assigned to each factor for every programming language. By collecting historical data, a data warehouse has been established, which stores the value of each

factor for every programming language. The programming language trends are described and evaluated by using these data.

Empirical research attempts to capture observed behaviors by empirical laws. In this dissertation, statistical methods are used to describe historical programming language trends and predict the evolution of the future trends. Several statistics models are constructed to describe the relationships among these factors. Canonical correlation is used to do the factor analysis. Multivariate multiple regression method has been used to construct the statistics models for programming language trends. After statistics models are constructed to describe the historical programming language trends, they are extended to do tentative prediction for future trends. The models are validated by comparing the predictive data and the actual data.

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by
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This dissertation is dedicated to
my beloved parents

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CHAPTER 1

SOFTWARE ENGINEERING TRENDS

1.1 Introduction

Software engineering is an engineering discipline whose goal is the cost-effective development of software systems. It was first proposed in 1968 at a conference held to discuss what was then called the "software crisis". Tremendous progress has been achieved since 1968 and the development of the software engineering discipline has markedly improved the practice of software development. A much better understanding of the activities involved in software development has been observed in past years. Although there is a lot of progress, many researchers still consider software engineering as a relatively young discipline. After a period of research about software engineering, there are more and more interests on the evolution of software engineering.

Predicting the evolution of software engineering technology is, at best, a dubious proposition. The recent evolution of software technology is a prime example; it is fast paced and affected by many factors, which are themselves driven by a wide range of sources. Many of the factors are outside the arena of software engineering and most of them cannot even be identified. Right now, this doctoral work is at the early, and tentative, stages of a project to analyze software engineering technology trends and how they evolve. In this dissertation, the author will discuss the tentative venture in this domain and sketch prospects for future research.

The purpose of this software engineering trends project is to analyze technology trends and try to gain some insight into how they evolve. While this doctoral dissertation is at the very early, and very tentative, stages of the whole project, research approaches of this problem could be characterized by two premises:

1. Structuring the problem. When approaching the problem of software engineering technology watch, there are many questions that beg for answers. All of these questions are interrelated: some questions refine others; some questions complement others; some questions provide the background for others; some questions overlap with others, etc. The first order of business, for this project, is to build a questionnaire structure, which arranges all these questions in a way that attempts to highlight their interrelations. Also, questionnaire structure should be improved by refining questions that are too vague, merging identical questions, or synthesizing related questions.
2. Specifying the solution. Three research methods should be distinguished: analytical research, which attempts to understand the phenomena that underlie observed behavior, and build models that capture these phenomena; empirical research, which makes no attempt to understand cause/effect relationships, but merely attempts to capture observed behaviors by empirical models; experimental research, which intervenes after analytical or empirical research to validate the proposed models. For each issue, it is useful to deploy a judicious combination of these three methods, or some subset thereof.

For the details of these research methods, they will be discussed later in this dissertation. These methods will be used as tools to analyze the evolution of software engineering.

1.2 Questionnaire Structure

To focus the effort on specific issues and to lend some structures to this inherently complex problem, a questionnaire has been built on a hierarchy of the following questions:

- How to watch software engineering trends? This question deals with what indicators are needed to monitor, where to find them, and how to interpret them.
- How to predict software engineering trends? This question deals with what lifecycle do software engineering trends follow, and what triggers the passage of a trend from one phase to another along the lifecycle.
- How to adapt to software engineering trends? This question deals with how does one define institutional strategy in such a way as to maximize benefit from what is known about a trend and minimize risk from what is not known about it.
- How to affect software engineering trends? Perhaps more crucial is whether trends can in fact be affected by any single entity. This question tries to identify where, in the cycle of a trend, is it possible to alter the course of the trend, and eventually how and by whom.

At the center of this hierarchy is the question of how to predict software engineering trends. If this question can be understood well, the others can be answered with adequate precision.

For each question, a judicious combination of the following three research methods or some subset thereof will be used:

- Analytical research, which attempts to understand the phenomena that underlie observed behavior, and build models that capture these phenomena.
- Empirical research, which makes no attempt to understand cause/effect relationships, but merely attempts to capture observed behaviors by empirical laws.
- Experimental research, which intervenes after analytical or empirical research to validate the proposed models.

1.3 Watching Software Engineering Trends

The general goal of watching software engineering trends is to determine what information must be maintained in order to gain a comprehensive view of the discipline and its evolution. The information in question must be sufficiently rich to support discipline-wide assessments as well as trend-specific analysis. The following questions will be asked to watch software engineering trends:

- What is the relevant information that must be collected/monitored?
- Where this information could be found, or where did it infer from?
- How to interpret this information?
- How often does it need to update this information?

A number of software engineering-specific, and technology-generic indicators have been identified, which have been divided into the following categories: Classification Standing, Research and Development, Science and Technology Output, Human Resources, Costs and Funding, Standards and Regulations, and Best Practices. [1]

Watching software engineering trends is the first step for the research on software engineering trends. Basically, the purpose of watching software engineering trends is to see the history of software engineering and analyze how it evolves. Then, a better understanding can be gained and some conclusions can be drawn. Watching software engineering trends is helpful to understand the future trends of software engineering.

1.4 Predicting Software Engineering Trends

The general goal of predicting software engineering trends is probably the most important and the most difficult goal of this whole study. The focus of this goal is on identifying a lifecycle that all trends follow. Once this lifecycle is identified, the software engineering trends can be predicted based on it.

Based on previous research, the lifecycle, which software engineering trends will follow, was recognized to be the following three cycles:

- Research Trends, which are a favorite topic of panel sessions and surveys.
- Technology Trends, which are driven by the maturation of applicable research ideas, and by the successful evolution of the idea to a useful, technologically viable, product.
- Market Trends, which are created either by the supply side or by the demand side in different situations.

For different trends, different methods will be used to analyze and predict them. In the author's point of view, empirical methods should be used to analyze research trends and technology trends, analytical research should be used for market trends. There are already some good analytical models for market trends, such as the Chasm Theory by Geoffrey A. Moore. This tentative research concentrates on research trends and technology trends.

1.5 Adapting to Software Engineering Trends

The general goal of adapting to software engineering trends is: "how to adapt to a trend if the trend has been known?" For example, a corporate manager hears about a particular trend (e.g. XML, .NET, Linux) and wants to know what to do about it: Ignore it? Adapt the corporate products and support it? Develop a new set of products that support it? Etc. When a party has a particular sake in the evolution of a trend, he/she may need a distinct information profile to make a judicious decision.

Adapting to technology trends depends to a large extent on watching technology trends and on predicting technology trends. If a corporate manager wants to make a decision on a given trend, what does he/she need to know about it? It is recognized that several features must be analyzed and/or quantified in order to provide support for this kind of decisions:

- What are the stakes of this trend for the organization?
- What are the intrinsic technical merits of this trend?
- What are the adoption costs of this trend?
- What are the adoption risks of this trend?

- What are the adoption benefits of this trend?
- How long is the trend expected to have an impact?
- What is the optimal time to make an adoption decision?

1.6 Affecting Software Engineering Trends

In this aspect of the project, there is an interest in analyzing to what extent it is possible to affect/control technology trends. It is not sufficient to have an impact on a trend. It is more important that thc impact can be premeditated and preplanned.

Detailing the general goals discussed above, the following questions have been derived:

- Is it possible to affect technology trends?
- Who can affect technology trends?
- How can technology trends be affected?
- How to quantify the impact?

1.7 Conclusion

Software engineering trends were briefly discussed in this chapter. The following is what need to be done in this tentative effort.

- First, try to formulate the problem of technology watch in terms of a hierarchy of increasingly specific questions. This hierarchy of questions serves two purposes: first to focus the effort on specific issues that need to be addressed; second to lend some structure to this inherently complex problem.

- Second, show how a systematic combination of empirical, experimental, and analytical approaches can give the researchers means to gain some understanding of the problem. Analytical approaches, mostly inspired from earlier work, will be used to derive candidate models for the complex evolution of software engineering trends; empirical approaches will be used to derive evolutionary models, or model aspects, without emphasis on analytical explanation of the models; and experimental approaches will be used to collect the necessary data to fill in the parameters of the candidate models and to test them for adequacy.

CHAPTER 2

FOCUS ON A FAMILY OF TRENDS: PROGRAMMING LANGUAGES

2.1 Introduction

At the early stage of the software engineering trends project, it is a good practice to concentrate on one particular field first. For example, what is the evolution process of operating system, computer networking, or database? This dissertation will focus on a family of software engineering trends: programming language trends.

Why programming languages should be selected as the first sample set for software engineering trends project? The followings are the reasons:

- First, it is well known that computer software consists of computer programs and associated documentation. Computer software is created in one or more programming languages and programming languages go hand-in-hand with software engineering.
- Second, it is also very important that programming language is a fundamental aspect of general-purpose computing, in contrast with *e.g.*, networks, operating systems, and databases.
- Third, the development of programming language in fact influenced the development of software engineering. By reviewing the history of programming language, a somewhat clearer view on software engineering could emerge.
- Fourth, hundreds of programming languages were created in the past, some of them were very successful, and some of them failed although a lot of resources were spent on them.

For the above reasons, it is clear that there is a good set and a rich history of programming languages that are well worth discussing. So, programming languages will be used as a good sample set for this research project.

2.2 History of Programming Languages

The original computer programming languages were the so-called machine languages. The human beings and the computers use the same language for programming. Machine language is great for computers but not so great for humans since the instructions are very simple and so many instructions are required. When programmers do programming, they have to spend a lot of time and energy to understand the machine language that is not very understandable for human beings. Machine language is also called First Generation Programming Language.

Second Generation Programming Languages were called assembly language. It's not easy for human beings to understand machine language, so researchers want to find other ways around for programmers. Assembly language turns the sequences of 0s and 1s into human words like 'add' that is much easier to understand by programmers. Assembly language could always be translated back into machine code by programs called assemblers.

Third Generation Programming Languages, which were also called High-Level Languages (HLL), were introduced for ease of programmability by humans. FORTRAN (FORmula TRANslator) was the first high-level language, which was developed in 1957 by a team led by Backus at IBM. [32] FORTRAN programs were translated or compiled into machine language to be executed. They didn't run as fast as hand-coded machine language programs, but FORTRAN nonetheless caught on very quickly because FORTRAN programmers were much more productive. There are many High-Level programming languages right now. C, C++, and Java are all Third Generation Programming Languages.

Fourth Generation Programming Languages (4GL) are programming languages closer to human languages than typical high-level programming languages. Most 4GLs are used to access databases. SQL is a Fourth Generation Programming Language. For example, a typical 4GL command is: FIND ALL RECORDS WHERE NAME IS "SMITH". As you see here, it is just the same as human language. So, 4GL is very easy to learn and programmer can have a better performance by using it.

Since most of existing programming languages are Third Generation Programming Languages, and they are also the most popular ones, only the Third Generation Programming Languages will be discussed in this dissertation. To avoid bias in some special fields, only the general-purpose programming languages will be discussed. Figure 2.1 shows the brief history of general-purpose High-Level Programming Languages (HLPL).

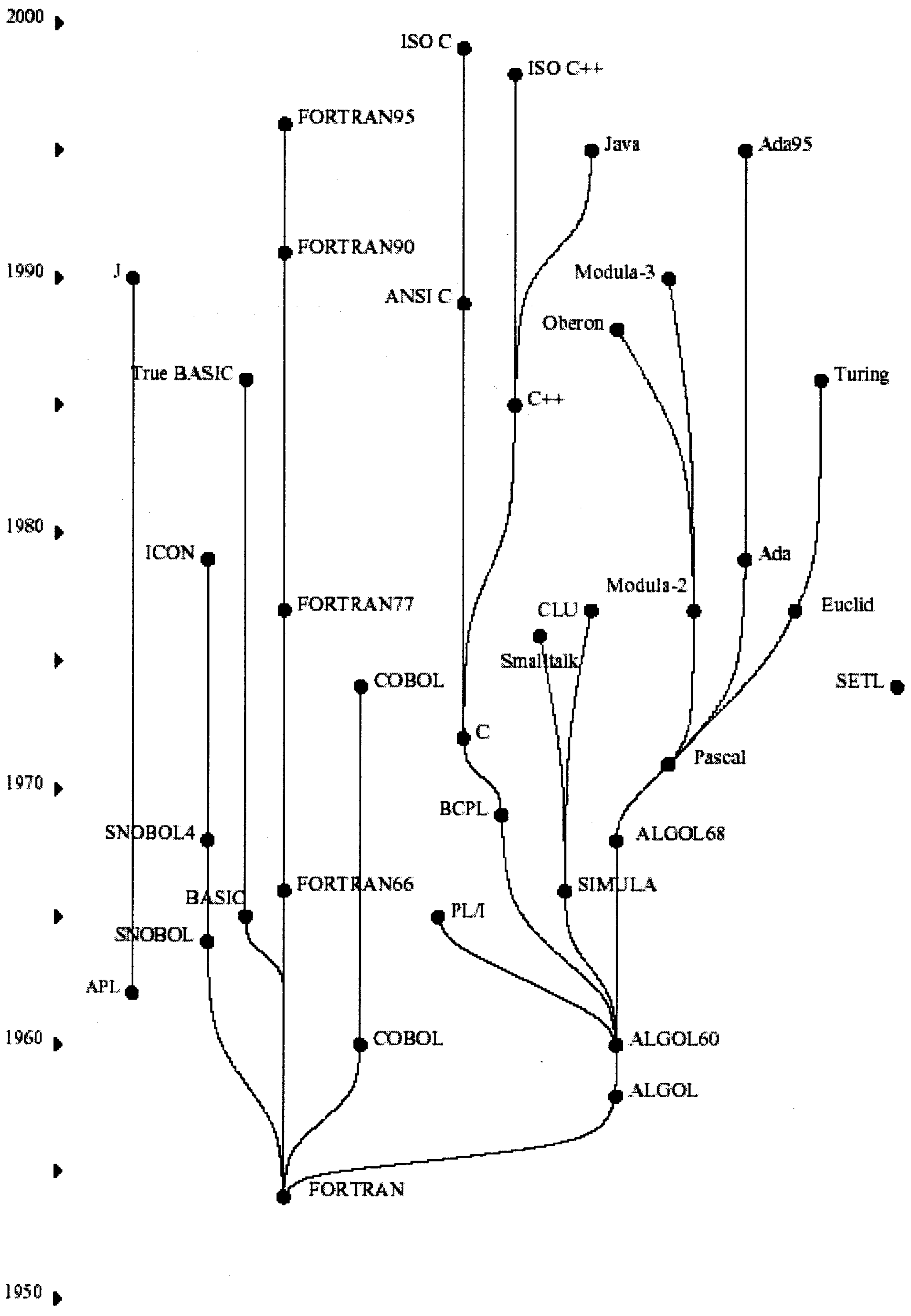


Figure 2.1 History of high level programming languages.

2.3 Programming Language Trends

Because programming language trends are part of software engineering trends, similar methods will be used to analyze them. This dissertation will concentrate on how to watch, predict, adapt to, and affect programming language trends.

The methods of how to watch, predict, adapt to, and affect software engineering trends have been discussed in chapter one. The historical trends of programming language will be discussed in the similar way. After having better understanding on the past trends, the author will concentrate on how to predict programming language trends. Empirical method will be used in this project.

To research the programming language trends, the following questions should be answered:

- Is it possible to predict if a programming language will succeed or fail?
- How to define success or failure?
- What are the possible factors that can affect the trend?
- What information should be collected in order to determine if a programming language succeed or fail?
- What are the factors that determine the success/failure?
- How to quantify the factors and find a model/function to predict the trends?
- How early can such factors be assessed?
- How early can the success/failure be predicted?

In this dissertation, all of these questions will be discussed. The answers of all these questions will form an outline for the whole programming language trends.

2.4 Research Methods

In this dissertation, the author will concentrate on how to watch, predict, adapt to, and affect programming language trends. From the evolution of software technology, the author think this evolution is affected by a dizzying array of factors, which are themselves driven by a wide range of sources. Monitoring programming language trends is not as untraceable as it may sound, that it does not have to be an ad-hoc, erratic process.

The following are the research methods:

- Find out the possible factors that maybe affect programming language trends
- Quantify those factors
- Analyze the history of programming languages
- Build statistical model(s) to watch evolution of programming languages
- Predict the future trends of programming languages
- Validate the statistical model(s)

Although it is impossible to find out "exact accurate" models for programming language trends, these models are useful and can be used to describe the history of programming languages. By extending the historical models, it could also be used to predict the future evolution of programming languages.

CHAPTER 3

SELECTING RELEVANT FACTORS

What are the possible factors that can affect the trend of programming languages? This is the question which will be discussed in chapter 3. To answer this question, research should be done in both the internal properties of programming languages themselves and the outside world which may have some influences on the programming languages trends, although it is not sure how they could affect the programming language trends.

By previous research, the author identified that two kinds of factors, intrinsic factors and extrinsic factors, could affect the programming language trends. Section 3.1 will discuss what are intrinsic factors and how to identify those factors. Section 3.2 will discuss extrinsic factors by the same methods.

3.1 Intrinsic Factors

Intrinsic factors are the factors that can be used to describe the general design criteria of programming languages. Completeness, orthogonal, and general significance need to be checked for the intrinsic factors in order to use them to evaluate a programming language.

Completeness

If one wants to use the intrinsic factors to evaluate a programming language, he/she would like to know if those factors are complete to describe a programming language. In the author's opinion, the above intrinsic factors are NOT complete, BUT desirable. In fact, it is impossible to find a complete set of factors which can be used to describe a programming language because there will always be new features as the development of a programming language. Just like what has been described in "Extensibility", which is one of the intrinsic factors. A programming language needs to be extended in the future. Someone may will ask this question: " How can you use these factors to evaluate a programming language if they are not complete?" The answer is: "Although the set is not complete, it could still be used." Why? Because these factors are widely considered desirable for most of the general-purpose programming languages and they are all important concern. The purpose of this project is to find out a useful framework which can be used to evaluate a programming language. These factors are definitely useful for this purpose.

Orthogonality

Another concern is about Orthogonality of these factors. Internal features of a programming language should not be mixed. In this chapter, a detailed definition has been given to each intrinsic factor. From the definition, it is clear that each factor is concentrating on one particular part of a programming language. Different factors are dealing with different aspects. Of course, nobody can guarantee that these factors are totally independent. Factor analysis will be used to solve this dependency.

General Significance

For all of these intrinsic factors, they should have general significance for every programming language. Basically, it should be fair for every programming language and no factors are "designed" for a specific language.

Because intrinsic factors are the factors that are used to describe the general design criteria of programming languages, they are constants for each programming language and will not change during the time. The following eleven factors have been identified as intrinsic factors of programming languages.

3.1.1 Generality

A programming language achieves generality by avoiding special cases in the availability or use of constructs and by combining closely related constructs into a single, more general one. ([11] pp. 52-53)

A language shall also provide generality to the extent necessary to satisfy the needs of embedded computer applications. Such applications involve real-time control, self-diagnostics, input-output to nonstandard peripheral devices, parallel processing, numeric computation, and file processing. [12]

Examples:

1) Pascal has procedure declarations and procedure value parameters, but no procedure variables. Thus the notion of procedure in Pascal lacks generality. This restriction is not in Modula-2, but remains in Ada where there are no procedure parameters. [13][14][15][18]

2) Pascal has no variable-length arrays, so arrays lack generality. C and Ada do have variable-length arrays, and Modula-2 and FORTRAN have the ability to pass variable-length array parameters, but cannot define variable-length array types. [13][14][18]

3) In Pascal and Modula-2 the equality operator "=" can be applied only to scalars, pointers, and sets, but not to arrays or records. Thus the "=" operator lacks generality. A similar restriction applies to C. Ada doesn't have this kind of restriction. [13][14][15][18]

4) In FORTRAN, there is only one parameter passing mechanism, pass by reference. Algol68, on the other hand, has only one parameter passing mechanism-pass by value- but achieves generality by allowing a pointer to any object to be passed by a value. FORTRAN has no such facility. [13][14][15][18]

5) In FORTRAN, named constants do not exist. In Pascal constants may not be expressions, while in Modula-2, constant expressions may not include function calls. Ada, however, has a completely general constant declaration facility. [13][14][15][18]

3.1.2 Orthogonality

Orthogonality in a programming language means that language constructs can be combined in any meaningful way and that the interaction of constructs, or the context of use, should not cause unexpected restrictions or behaviors. ([11] pp.53-54) [12]

Examples:

1) In PASCAL, functions can return only scalar or pointer types as values. In C, values of all data types except array types can be returned from a function (indeed arrays are treated in C differently from all other types). Ada doesn't have this limitation. [13][14]

2) In PASCAL, file types have a special status and thus cause a number of nonorthogonalities. For example, files cannot be passed by value to procedures, and

assignment to file variables is prohibited. In many other languages files are part of a (system dependent) library instead of the language definition, thus avoiding such nonorthogonalities. [13][14][15]

3) In Modula-2, strings can be assigned to string variables of greater length, but not vice versa; this is the only case in Modula-2 where assignment works for unequal-size objects.

4) In C, there is a nonorthogonality in parameter passing: C passes all parameters by value except array, which is passed by reference. [13]

3.1.3 Reliability

A language should be designed to avoid error prone features and to maximize automatic detection of programming errors. A language should aid the design and development of reliable programs. A language should also require some redundant, but not duplicative, specifications in programs. Translators should produce explanatory diagnostic and warning messages, but should not attempt to correct programming errors. [12] [11](p.51)

Examples:

1) Ada requires separate specifications for all modules other than stand-alone subprograms.

2) C and C++ contain many well-known traps (= vs. ==, & vs. &&, premature semicolon in control structures, fall-through behavior in switch statements when "break" is omitted); some were removed or made less likely in Java but others were not.

3) C permits separate specifications (through prototypes) but optional; function names are globally accessible by default and can be incorrectly redefined. C++ supports

separate specifications and has a slightly tighter type system than C. Also, good use of C++'s object-oriented features should increase the likelihood of compile-time detection of some kinds of errors. Java automatically generates specifications (as opposed to using redundant specifications).

4) C and C++ do little checking at run-time. Both Ada and Java perform a number of run-time checks (e.g. bounds checking and checks for null values) to detect errors early. [13][14][15][18]

3.1.4 Maintainability

A language should emphasize program readability (i.e., clarity, understandability, and modifiability of programs). A language should promote ease of program maintenance. The language should encourage user documentation of programs. It shall require explicit specification of programmer decisions and shall provide defaults only for instances where the default is stated in the language definition, is always meaningful, reflects the most frequent usage in programs, and may be explicitly overridden. [12] [11](p.52)

Examples:

1) Ada was originally designed with readability in mind. C was not, and can easily be abused to make impenetrable code.

2) C (and hence C++ and Java) includes a great deal of terse notation which reduces readability (e.g. the "for" loop notation, using "&&" instead of "and", and operators such as "<<").

3) C++'s object-oriented features, if used, are likely to improve maintainability (because they force interfaces to be defined and used). Java's document comments (//*)

and standard documentation conventions aid in readability. Note that "readability" of a programming language is extremely subjective - well-structured programs can be read and maintained in any language by someone who knows the language, and no language can prevent all poor approaches. At issue in this requirement is how strongly the language encourages readable and maintainable code. [13][14][15][18]

3.1.5 Efficiency

Features should be chosen to have a simple and efficient implementation in many object machines, to avoid execution costs for available generality where it is not needed, to maximize the number of safe optimizations available to translators, and to ensure that unused and constant portions of programs will not add to execution costs. Constructs that have unexpectedly expensive implementations should be easily recognizable by translators and by users. Execution time support packages of the language shall not be included in object code unless they are called. A language design should aid the production of efficient programs. [11](pp. 49-52) [12]

Examples:

1) Ada functions returning unbounded size objects usually have hidden extra efficiency costs (access types can be used where this is important).

2) C++ implicit conversion operations may be activated in situations not easily recognizable by its users. C/C++ pointer arithmetic and aliasing prohibit some optimizations.

3) Java's garbage collection raises questions about efficiency and guaranteed timing, especially in real-time systems. [13][14][15][18]

3.1.6 Simplicity

A language should not contain unnecessary complexity. A language should have a consistent semantic structure that minimizes the number of underlying concepts. A language should be as small as possible consistent with the needs of the intended applications. A language should have few special cases and should be composed from features that are individually simple in their semantics. A language should have uniform syntactic conventions and should not provide several notations for the same concept. No arbitrary restriction should be imposed on a language feature. [11] (p. 55) [12]

Examples:

1) Ada includes both Ada 83's discriminated records and the newer (OO) tagged types (these have many similarities).

2) C is a very simple language (though not necessarily simple to use). C++ has C operations and its own operations (new/delete vs. malloc/free, cout vs. printf). [13][14][15][18]

3.1.7 Machine Independence

A language should not dictate the characteristics of object machines or operating systems except to the extent that such characteristics are implied by the semantics of control structures and built-in operations. A language should attempt to avoid features whose semantics depend on characteristics of the object machine or of the object machine operating system. Nevertheless, there shall be a facility for defining those portions of programs that are dependent on the object machine configuration and for conditionally compiling programs depending on the actual configuration. The design of a language should strive for machine independence. [12] [11](p. 56)

Examples:

1) Ada includes a number of mechanisms to query the underlying configuration (such as bit ordering conventions) and C/C++ include some querying mechanisms.

2) Conditional compilation in Ada and Java is handled through "if (constant)" statements (this does not permit conditional compilation in cases where "if" statements are not permitted).

3) Java has few mechanisms for querying the underlying configuration and imposes requirements on bit length and semantics of numeric types that must be supported. Java strives for machine independence by hiding the underlying machine. [13][14][15][18]

3.1.8 Implementability

A language should be composed from features that are understood and can be implemented. The semantics of each feature should be sufficiently well specified and understandable that it will be possible to predict its interaction with other features. To the extent that it does not interfere with other requirements, the language should facilitate the production of translators that are easy to implement and are efficient during translation. There should be no language restrictions that are not enforceable by translators. [12] [11](p.51)

3.1.9 Extensibility

This principle advocates that there should be some general mechanism for the user to add features to a language. C++ added object-oriented feature to C which shows that C has a good extensibility. It is also relatively easy to add new structures and third-party libraries for C++. JAVA also has good extensibility by including useful library in its language features. [12] [11](pp. 57-58)

3.1.10 Expressiveness

Expressiveness is the ease with which a language can express complex processes and structures. It could be measured by the lines of code (LOC) per function unit. Table 3.1 [86] shows the average LOC per function unit for different generations of programming languages. It is clear that 3rd and 4th generation languages are more expressive than 1st and 2nd generation languages.

Table 3.1 Lines of Code per Function Unit

Languages	LOC per function unit
1st Generation Languages	320
2nd Generation Languages	107
3rd Generation Languages	50
4th Generation Languages	20

One of the original advances in expressiveness was the addition of recursion to programming languages. LISP is expressive in both data and program. Expressiveness can conflict with simplicity: LISP, Prolog, and Algol68 are extremely expressive that are not simple.

3.1.11 Influence/Impact

This factor will check how this language influence the other languages and what is the impact of this language to the other ones.

Table 3.2 Number of Descendents for Programming Languages

Languages	Number of Descendents
ADA	1
ALGOL	6
APL	1
C	3
C++	2
COBOL	1
EIFFEL	1
FORTRAN	15
JAVA	1
LISP	1
ML	1
MODULA	2
PASCAL	6
PROLOG	1
SCHEME	1
SMALLTALK	1

Basically, the author will check how many dialects a programming language has; how many descendents a programming language has; how many languages are directly influenced by a programming language, etc. Table 3.2 shows the number of descendents for some programming languages.

3.2 Extrinsic Factors

From the previous section, it shows that intrinsic factors are the attributes of a programming language itself. After identifying a set of intrinsic factors, the following questions need to be asked:

1) Are intrinsic factors enough to determine the future of a programming language?

2) Are there any other factors that can also affect the trend of a programming language?

3) If the answer is "Yes" for 2), what should the other factors be?

The recent evolution of programming language is a prime example of this evasiveness, because this evolution is affected by a dizzying array of factors, which are themselves driven by a wide range of sources, such as market forces, corporations, government agencies, standards bodies, universities, etc. In the author's point of view, the outside world will also have big impact on the trend of each programming language.

So, what could be the possible outside factors in the world that could affect the trends of programming languages? The rest of the chapter three will discuss this question.

Extrinsic factors are the factors that are not directly related to the general attributes of a programming language, but still can affect the trend of programming language. The author's purpose is to find out as many as possible factors from "outside world" which may affect the trend of a programming language. Right now, the extrinsic factors have been classified into the following seven categories: Institutional Support, Industrial Support, Governmental Support, Organizational Support, Grassroots Support, and Technology Support. Each category includes several questions.

3.2.1 Institutional Support

- Is this language introduced and supported by any institution? (Genesis of this language)
- How many institutions use this language as the support for introductory programming courses?
- How many students have used this language for their introductory programming courses?
- How many institutions use this language as the support for any courses?
- How many students have used this language for any of their courses?
- How many research projects use this language as support?
- How many research projects deal with this language as subject?

3.2.2 Industrial Support

- Is this language introduced and supported by any Company?
- Are there any industrial standards for this language (defined by standards bodies)?
- How many companies use this language as primary language to develop products?
- How many developers consider this language as their primary language?
- How many companies use this language as support for any of their products?
- How many developers know about this language?
- How many commercial applications are developed by using this language?

3.2.3 Governmental Support

- Is this language introduced and supported by any government/agency?
- Are there any government standards for this language?
- How much has the government invested in this language?
- How much code is written for government in this language?

3.2.4 Organizational Support

- Is this language introduced and supported by any (international) organization?
- Are there any organizational standards?
- How many conferences are held for this programming language?

- How many conference papers/articles are published on this programming language?
- How many conference papers/articles are published by using this programming language as support?

3.2.5 Grassroots Support

- How many people know this Language?
- How many people consider this Language as their primary programming Language?
- How much code is written in this Language?
- How many user groups are dedicated to this language?

3.2.6 Technology Support

- How many compilers/Interpreters are available for this language?
- How many debuggers are available for this language?
- How many IDEs/CASE tools available for this language?
- How many libraries (including third-party libraries) are available for this language?
- How many operating systems support this language?

In the author's point of view, both intrinsic factors and extrinsic factors could impact on the evolution of programming languages. Identifying these factors is the first step for this empirical study.

CHAPTER 4

QUANTIFYING RELEVANT FACTORS

As discussed before, empirical method will be used in this dissertation to analyze the data. So, after selecting a set of factors, a new question comes up: How to quantify these factors?

In this chapter, the question above will be divided into two questions: How to quantify intrinsic factors and how to quantify extrinsic factors?

4.1 Quantifying Intrinsic Factors

All of the intrinsic factors should be considered when one designs a programming language. So, all features of a programming language should be checked to see if it matches these factors. In this section, the author will check each intrinsic factor and discuss how to quantify it.

Table 4.1 shows how to quantify "generality". Table 4.1 shows that the following sub-factors could be examined in order to give a score to "generality" because each of the following sub-factors shows some kind of "generality". They will be sorted from weakest to strongest and assign a score for each of these sub-factors. For example, abstract data template (ADT), which represents high-level generality, should be checked in order to measure generality of a programming language.

For other intrinsic factors, the similar methods will be used to quantify them. Please check Table 4.2 to Table 4.11 for details.

Table 4.1 Features Used to Quantify Generality

Sub factors	Score
Offering constant literals	1
General constant declaration facility	2
Type Conversion	3
Variant records	4
Variable size array	5
Overloading	6
Variability in number of arguments (Default argument)	7
Variability in order of arguments	8
Using function as parameters(Parameter passing mechanism)	9
Generic ADTs (Template)	10

Table 4.2 Features Used to Quantify Orthogonality

Sub factors	Score
Uniformity in function arguments	1
Uniformity in operator arguments	2
Uniformity in return values	3
Uniformity in comparison arguments	4
Uniformity in expression representation (function substitutability)	5

Table 4.3 Features Used to Quantify Reliability

Sub factors	Score
Block structure	1
Bounds check	2
Strong Typing	3
Information Hiding	4
Exception Handling	5

Table 4.4 Features Used to Quantify Maintainability

Sub factors	Score
Natural Notation	1
Program/Block Structure	2
Modularity	3
Inheritance	4
Polymorphism	5

Table 4.5 Features Used to Quantify Efficiency

Sub factors	Score
Memory Management	1
Garbage Collection	2

Table 4.6 Features Used to Quantify Simplicity

Sub factors	Score
Size of BNF	1
Economy of Concept	2

Table 4.7 Features Used to Quantify Implementability

Sub factors	Score
Size/Complex of current compilers	1

Table 4.8 Features Used to Quantify Machine Independence

Sub factors	Score
Number of machines that support this language	1

Table 4.9 Features Used to Quantify Extensibility

Sub factors	Score
Support for Macros	1
Support for Language defined operator overloading	2

Table 4.10 Features Used to Quantify Expressiveness

Sub factors	Score
LOC per function unit	1

Table 4.11 Features Used to Quantify Impact/Influence

Sub factors	Score
How many dialects for this programming language?	
How many descendents for this programming language?	
How many languages are directly influenced by this programming language?	

4.2 Quantifying Extrinsic Factors

Extrinsic factors are not like intrinsic factors. Basically, they are questions for different fields. Most of the questions are asking for the numbers, so the numbers can be directly used as the value of this extrinsic factor. No specific method needed for quantifying extrinsic factors.

Although extrinsic factors don't need quantification, how to get the answers of these factors is still a big problem. Chapter five will discuss how to collect data for both intrinsic and extrinsic factors.

CHAPTER 5

DATA COLLECTION

5.1 Language List

To watch and predict the trends of programming languages, a set of programming languages should be selected as samples. By analyzing this set of programming languages, statistics models will be constructed to describe the past trends of programming languages. By extending the statistics models, they will also be used to predict the future trend of a programming language.

In this chapter, the following programming languages will be investigated: ADA, ALGOL, APL, BASIC, C, C++, COBOL, EIFFEL, FORTRAN, JAVA, LISP, ML, MODULA, PASCAL, PROLOG, SCHEME, SMALLTALK. After reviewing the brief history and language features of each programming language, how to collect data for intrinsic factors and extrinsic factors will be discussed. [67]

5.2 Watching Programming Languages

5.2.1 ADA

The Ada language is the result of the most extensive and most expensive language design effort ever undertaken. Up until 1974 half of the applications at The Department of Defense (DoD) were embedded systems. An embedded system is one where the computer hardware is embedded in the device it controls. More than 450 programming languages were used to implement different DoD projects, and none of them were standardized. Because of this, software was rarely reused. For these reasons, the Army, Navy, and Air Force proposed to develop a high-level language for embedded systems. [67]

By 1977, a complete language design specification for Ada was created. In April 1977, four proposing contractors were chosen to produce Phase I of the language design. In February 1977, Phase I of the language design was complete. Following this was a two-month evaluation period where 400 volunteers in 80 teams chose two out of the four as being the best language designs. These two companies were then given the go ahead to produce Phase II of the project. At the end of Phase II, another two-month evaluation period took place. In May of 1979 the Cii Honeywell/Bull (the only foreign contractor) language design was chosen as the winner. Phase III of the project began after the winner was selected. After a winner was selected, the language design was published by the ACM. In November 1979, over 500 language reports were received from 15 different countries. Most of the reports suggested minor changes in the design, none real drastic. Based on these suggestions, a revised language design was published in February of 1980. After some minor changes to this document over the next few years, the final official version of the language was settled upon. The Ada language was then frozen for the next five years.

Ada has the following significant language features:

- Packages: Data types, data objects, and procedure specifications can be encapsulated into a package. This supports the program design of data abstraction.
- Exception Handling: Ada has very good exception handling capabilities which allow the program to handle its own run-time errors.

- Generic Program Units: It is possible to write a procedure (for example, a sorting procedure) which does not require a data type to be specified.
- Parallel / Concurrent Processing: Ada supports parallel and concurrent execution of tasks.
- Ada 95 Added:
    - Support for object-oriented programming
    - More flexible libraries
    - Better control mechanisms for shared data

5.2.2 ALGOL

ALGOL (ALGOrithmic Language) is one of several high level languages designed specifically for programming scientific computations. It started out in the late 1950's, first formalized in a report titled ALGOL 58, and then progressed through reports ALGOL 60, and ALGOL 68. It was designed by an international committee to be a universal language. Their original conference, which took place in Zurich, was one of the first formal attempts to address the issue of software portability. ALGOL's machine independence permitted the designers to be more creative, but it made implementation much more difficult. Although ALGOL never reached the level of commercial popularity of FORTRAN and COBOL, it is considered the most important language of its era in terms of its influence on later language development. ALGOL’s lexical and syntactic structures became so popular that virtually all languages designed since have been referred to as "ALGOL - like"; that is they have been hierarchical in structure with nesting of both environments and control structures. [67]

ALGOL was the first second-generation programming language and its characteristics are typical of the entire generation. First consider the data structures, which are very close to first generation structures. In ALGOL 60 the block structure was introduced: the ability to create blocks of statements for the scope of variables and the extent of influence of control statements. Along with that, two different means of passing parameters to subprograms; call by value and call by name. Structured control statements: if - then - else and the use of a general condition for iteration control were also features, as was the concept of recursion: the ability of a procedure to call itself.

One of the greatest impacts ALGOL 60 had was a result of its description as found in Naur (1963). A major contribution of this report was the introduction of BNF notation for defining the syntax of the language. Overall, ALGOL is considered to be perhaps the most orthogonal programming language, meaning it has a relatively small number of basic constructs and a set of rules for combining those constructs. Every construct has a type associated with it and there are no restrictions on those types. In addition, most constructs produce values. Several of ALGOL's other characteristics are listed below:

- Dynamic Arrays: one for which the subscript range is specified by variables so that the size of the array is set at the time storage is allocated.
- Reserved Words: the symbols used for keywords are not allowed to be used as identifiers by the programmer.
- User defined data types: allow the user to design data abstractions that fit particular problems very closely.

ALGOL was used mostly by research computer scientists in the United States and in Europe. Its use in commercial applications was hindered by the absence of standard input/output facilities in its description and the lack of interest in the language by large computer vendors. ALGOL 60 did however become the standard for the publication of algorithms and had a profound effect on future language development.

5.2.3 APL

APL stands for "A Programming Language." Ken Iverson and his colleagues at IBM created it in the 1960's. [67]

Mathematically inspired, APL's main purpose was to serve as a powerful executable notation for mathematical algorithms. What APL is best known for is its use of non-ASCII symbols, including some Greek letters, and the scale of its operation. It is a dynamically typed interactive, array-oriented language with a dynamic scope. In APL, all expressions are evaluated from right to left.

APL has the following significant language features:

- Non-Standard Character Set: APL makes use of a character set which contains some non-ASCII characters, including some Greek letters.
- Dynamic Array Universe: APL's environment consists of arrays, created dynamically.
- Interaction: APL is an interactive language.

5.2.4 BASIC

BASIC (standing for Beginner's All Purpose Symbolic Instruction Code) is a system developed at Dartmouth College in 1964 under the directory of J. Kemeney and T. Kurtz. It was implemented for the G.E.225. It was meant to be a very simple language to learn and also one that would be easy to translate. Furthermore, the designers wished it to be a stepping-stone for students to learn the more powerful languages such as FORTRAN or ALGOL. [67]

Different BASIC versions were originated from Gordon Eubanks (The CEO and president of Symantec) who, in 1970, developed BASIC-E. BASIC-E used a technique similar to the one currently used by Java; instructions were transformed into a kind of intermediate code and then converted into machine readable code. Eubanks also did not protect BASIC-E but he did with his following version, CBASIC. CBASIC was marketed by his company, Compiler Systems (which in 1981 was acquired by Digital Research). BASIC versions were so rapidly appearing that ANSI (American National Standard Institute) recognized in 1974 the need for a standard implementation of the BASIC language. A committee started working on two standard one called minimal BASIC and the other Standard BASIC. Standardization was completed long after the use of BASIC had spread worldwide, and Standard BASIC never appeared. ANSI issued two specifications: one for Minimal Basic in 1978 (specification X3.60-1978) and the other in 1987 for the Standard BASIC (specification X3.113-1987). These standards were also issued by the ISO (ISO 6373-1984 for the Minimal BASIC and ISO 10279-1991 for the Full BASIC).

Since the early-1980s the history of BASIC and computing followed a tightly-bound and parallel course. IBM on the PC released an interpreted BASIC on ROM which could be enhanced by loading an additional extension known as BASICA. Essentially BASICA, which was on every PC-DOS distribution diskettes set, and its MS-DOS analog, the Gee-Witz (or GW) BASIC, dominated the market in the PC market. In 1984 Microsoft released the BASIC compiler (known as BASCOM from the .exe file) which again permitted compiled BASIC. This was a new breakpoint in BASIC's history. From that time on new powerful versions of BASIC appeared on the market every few months.

Microsoft Quick BASIC launched in 1985 as version 1.0, reached version 4.5 in 1988. In the meanwhile BASIC changed a lot, acquiring structured syntax, sub-functions, user defined data, multi-file programs and, in 1990 with the Microsoft BASIC Professional Development System 7.1, gained even full access to the memory outside 64K. Again the operating system for computers drove the direction of BASIC when the Windows platform was introduced. This resulted in the development of Visual BASIC which was designed for GUI applications. Visual BASIC claims also to be an object-oriented language although many programmers do not completely agree on this. They mean Visual Basic is only object based.

5.2.5 C

Dennis Ritchie developed C at Bell Laboratories in 1972. Many of its principles and ideas were taken from the earlier language B and B's earlier ancestors BCPL and CPL. CPL (Combined Programming Language) was developed with the purpose of creating a language that was capable of both high level, machine independent programming and would still allow the programmer to control the behavior of individual bits of information. The one major drawback of CPL was that it was too large for use in many applications. In 1967, BCPL (Basic CPL) was created as a scaled down version of CPL while still retaining its basic features. In 1970, Ken Thompson, while working at Bell Labs, took this process further by developing the B language. B was a scaled down version of BCPL written specifically for use in systems programming. Finally in 1972, a co-worker of Ken Thompson, Dennis Ritchie, returned some of the generality found in BCPL to the B language in the process of developing the language that is known as C right now. [67]

C's power and flexibility soon became apparent. Because of this, the Unix operating system which was originally written in assembly language, was almost immediately re-written in C (only the assembly language code needed to "bootstrap" the C code was kept). During the rest of the 1970's, C spread throughout many colleges and universities because of it's close ties to Unix and the availability of C compilers. Soon, many different organizations began using their own versions of C causing compatibility problems. In response to this in 1983, the American National Standards Institute (ANSI) formed a committee to establish a standard definition of C which became known as ANSI Standard C. Today C is in widespread use with a rich standard library of functions.

C is a powerful, flexible language that provides fast program execution and imposes few constraints on the programmer. It allows low level access to information and commands while still retaining the portability and syntax of a high level language. These qualities make it a useful language for both systems programming and general-purpose programs.

C's power and fast program execution come from it's ability to access low level commands, similar to assembly language, but with high level syntax. It's flexibility comes from the many ways the programmer has to accomplish the same tasks. C includes bitwise operators along with powerful pointer manipulation capabilities. C imposes few constraints on the programmer. The main area this shows up is in C's lack of type checking. This can be a powerful advantage to an experienced programmer but a dangerous disadvantage to a novice.

Another strong point of C is its use of modularity. Sections of code can be stored in libraries for re-use in future programs. This concept of modularity also helps with C's portability and execution speed. The core C language leaves out many features included in the core of other languages. These functions are instead stored in the C Standard Library where they can be called on when needed.. An example of this concept would be C's lack of built in I/O capabilities. I/O functions tend to slow down program execution and also be machine independent when running optimally. For these reasons, they are stored in a library separately from the C language and only included when necessary.

5.2.6 C++

The C++ programming language is an extension of C that was developed by Bjarne Stroustrup in the early 1980s at Bell Laboratories. C++ provides a number of features that "spruce up" the C language, but more importantly, it provides capabilities for object-oriented programming. [67]

Object-oriented programs are easier to understand, correct and modify. Many other object-oriented languages have been developed, including most notably, Smalltalk. The best features of C++ are:

- C++ is a hybrid language-it is possible to program in either a C-like style, an object-oriented style, or both.
- C++ programs consist of pieces called classes and functions. You can program each piece you may need to form a C++ program. The advantage of creating your own functions and classes is that you will know exactly how they work. You will be able to examine the C++ code.

C++ provides a collection of predefined classes, along with the capability of user-defined classes. The classes of C++ are data types, which can be instantiated any number of times. Class definitions specify data objects (called data members) and functions (called member function). Classes can name one or more parent classes, providing inheritance and multiple inheritances, respectively.

5.2.7 COBOL

COBOL (Common Business Oriented Language) was one of the earliest high-level programming languages. It was developed in 1959 by a group of computer professionals called the Conference on Data Systems Languages (CODASYL). Since 1959 it has undergone several modifications and improvements. In an attempt to overcome the problem of incompatibility between different versions of COBOL, the American National Standards Institute (ANSI) developed a standard form of the language in 1968. This version was known as American National Standard (ANS) COBOL. In 1974, ANSI published a revised version of (ANS) COBOL, containing a number of features that were not in the 1968 version. In 1985, ANSI published still another revised version that had new features not in the 1974 standard. The language continues to evolve today. Object-oriented COBOL is a subset of COBOL 97, which is the fourth edition in the continuing evolution of ANSI/ISO standard COBOL. COBOL 97 includes conventional improvements as well as object-oriented features. Like the C++ programming language, object-oriented COBOL compilers are available even as the language moves toward standardization. [67]

COBOL, long associated with green screens, core dumps, and traditional mainframe connections, may at first glance seem at odds with object technology, push-button graphical interfaces, and interactive development environments. This perceived incongruity, however, is more a reflection of the mainframe's ability to keep pace with the innovations of desktop and client-server computing than a flaw in the COBOL language. The following are the significant features for COBOL:

- The language that automated business
- Allows names to be truly connotative: permits both long names (up to 30 characters) and word-connector characters (dashes)
- Every variable is defined in detail: this includes number of decimal digits and the location of the implied decimal point
- File records are also described with great detail, as are lines to be output to a printer - ideal for printing accounting reports
- Offers object, visual programming environments

- Class Libraries
- Rapid Application Capabilities
- Integration with the World Wide Web

COBOL is ideally suited for the solution of business problems. For example, if a company wanted to keep track of its employees' annual wages, COBOL would be ideal language for implementation. It is interesting to note that COBOL was the first programming language whose use was mandated by the Department of Defense (DoD).

5.2.8 EIFFEL

The Eiffel programming language was created by Bertrand Meyer and developed by his company, Interactive Software Engineering (ISE) of Goleta, CA in 1985. Eiffel has evolved continually since its conception on September 14, 1985 and its first introduction in 1986. Eiffel is named after Gustave Eiffel, the engineer who designed the Eiffel Tower. The developers of Eiffel like to compare themselves to the well-built structure of the Eiffel Tower. The Eiffel Tower was completed on time and within budget, which should happen if you use Eiffel for your software projects. There are several significant language features of Eiffel: [67]

- Portable: this language is available for major industry platforms, such as Windows, OS/2, Linux, UNIX, VMS, etc...
- Open System: includes a C and C++ interface making it easily possible to reuse code previously written.

- "Melting Ice Technology": combines compilation, for the generation of efficient code, with byte-code interpretation, for fast turnaround after a change.
- "Design by Contract": enforced through assertions such as class invariants, preconditions and post-conditions.
- Automatic Documentation ("Short Form"): abstract yet precise documentation produced by the environment at the click of a button.
- Multiple Inheritance: a class can inherit from as many parents as necessary.
- Repeated Inheritance: a class inherits from another through two or more parents.
- Statically Typed: ensure that errors are caught at compile time, rather than run time.
- Dynamically Bound: guarantees that the right version of an operation will always be applied depending on the target object.

5.2.9 FORTRAN

One of the oldest programming languages, the FORTRAN was developed by a team of programmers at IBM led by John Backus, and was first published in 1957. The name FORTRAN is an acronym for FORmula TRANslation, because it was designed to allow easy translation of math formulas into code. [67]

Often referred to as a scientific language, FORTRAN was the first high-level language, using the first compiler ever developed. Prior to the development of FORTRAN computer programmers were required to program in machine/assembly code, which was an extremely difficult and time consuming task, not to mention the dreadful chore of debugging the code. The objective during it's design was to create a programming language that would be: simple to learn, suitable for a wide variety of applications, *machine independent*, and would allow complex mathematical expressions to be stated similarly to regular algebraic notation. It is still almost as efficient in execution as assembly language. Since FORTRAN was so much easier to code, programmers were able to write programs 500% faster than before, while execution efficiency was only reduced by 20%, this allowed them to focus more on the problem solving aspects of a problem, and less on coding.

FORTRAN was so innovative not only because it was the first high-level language, but also because of it's compiler, which is credited as giving rise to the branch of computer science now known as compiler theory. Several years after it's release FORTRAN had developed many different dialects, (due to special tweaking by programmers trying to make it better suit their personal needs) making it very difficult to transfer programs from one machine to another.

These problems lead the *American Standards Association* (now known as the American National Standards Association) to release it's first Standard for a Programming Language in 1966. This first standardized version has come to be known as FORTRAN '66 (aka.. FORTRAN IV).

Despite this standardization, a few years later, various new *dialects* began to surface again, requiring the Standards Association review the language again. This version is known as FORTRAN '77. This version was released in 1978 (it was called '77 because the Association began it's review in 1977), with several new features. Some of the more notable properties were; new error handling methods, and mechanisms for managing large-scale programs. The latest version; Fortran '90 (released in 1990, using the new capitalization scheme) added even more new features, such as support for: recursion, pointers, and for programmer-defined data types. Some of the more significant features of Fortran are as listed below:

- Simple to learn: when FORTRAN was design one of the objectives was to write a language that was easy to learn and understand.
- Machine Independent: allows for easy transportation of a program from one machine to another.
- More natural ways to express mathematical functions: FORTRAN permits even severely complex mathematical functions to be expressed similarly to regular algebraic notation.
- Problem orientated language
- Remains close to and exploits the available hardware
- Efficient execution: there is only an approximate 20% decrease in efficiency as compared to assembly/machine code.
- Ability to control storage allocation: programmers were able to easily control the allocation of storage (although this is considered to be a dangerous practice today, it was quite important some time ago due to limited memory.
- More freedom in code layout: unlike assembly/machine language, code does not need to be laid out in rigidly defined columns, (though it still must remain within the parameters of the FORTRAN source code form).

FORTRAN is useful for a wide variety of applications. Some of the more outstanding ones are as follows:

- Number crunching: due to the more natural (like it's true algebraic form) way of expressing complex mathematical functions and it's quick execution time, FORTRAN is easy and efficient at processing mathematical equations.
- Scientific, mathematical, statistical, and engineering type procedures: due to it's rapid number-crunching ability FORTRAN is a good choice for these type of applications.

Basically FORTRAN is most useful for applications that are "computational-bound" rather than "I/O bound".

5.2.10 JAVA

The Java programming Language evolved from a language named Oak. Oak was developed in the early nineties at Sun Microsystems as a platform-independent language aimed at allowing entertainment appliances such as video game consoles and VCRs to communicate. Oak was first slated to appear in television set-top boxes designed to provide video-on-demand services. Just as the deals with the set-top box manufacturers were falling through, the World Wide Web was coming to life. As Oak's developers began to re cognize this trend, their focus shifted to the Internet and WebRunner, an Oak-enabled browser, was born. Oak's name was changed to Java and WebRunner became the HotJava web browser. The excitement of the Internet attracted software vendors such that Jav a development tools from many vendors quickly became available. That same excitement has provided the impetus for a multitude of software developers to discover Java and its many wonderful features. Java has the following significant features: [67]

- Platform Independence: Java compilers do not produce native object code for a particular platform but rather 'byte code' instructions for the Java Virtual Machine (JVM). Making Java code work on a particular platform is then simply a matter of writing a byte code interpreter to simulate a JVM. What this all means is that the same compiled byte code will run unmodified on any platform that supports Java.
- Object Orientation: Java is a pure object-oriented language. This means that everything in a Java program is an object and everything is descended from a root object class.
- Rich Standard Library: One of Java's most attractive features is its standard library. The Java environment includes hundreds of classes and methods in six major functional areas.
    - Language Support classes for advanced language features such as strings, arrays, threads, and exception handling.
    - Utility classes like a random number generator, date and time functions, and container classes.
    - Input/output classes to read and write data of many types to and from a variety of sources.
    - Networking classes to allow inter-computer communications over a local network or the Internet.

  - Abstract Window Toolkit for creating platform-independent GUI applications.
  - Applet is a class that lets you create Java programs that can be downloaded and run on a client browser.
- Applet Interface: In addition to being able to create stand-alone applications, Java developers can create programs that can be downloaded from a web page and run on a client browser.
- Familiar C++-like Syntax: One of the factors enabling the rapid adoption of Java is the similarity of the Java syntax to that of the popular C++ programming language.
- Garbage Collection: Java does not require programmers to explicitly free dynamically allocated memory. This makes Java programs easier to write and less prone to memory errors.

5.2.11 LISP

Interest in artificial intelligence first surfaced in the mid 1950. Linguistics, psychology, and mathematics were only some areas of application for AI. Linguists were concerned with natural language processing, while psychologists were interested in modeling human information and retrieval. Mathematicians were more interested in automating the theorem proving process. The common need among all of these applications was a method to allow computers to process symbolic data in lists. [67]

IBM was one of the first companies interested in AI in the 1950s. At the same time, the FORTRAN project was still going on. Because of the high cost associated with producing the first FORTRAN compiler, they decided to include the list processing functionality into FORTRAN. The FORTRAN List Processing Language (FLPL) was designed and implemented as an extension to FORTRAN.

In 1958 John McCarthy took a summer position at the IBM Information Research Department. He was hired to create a set of requirements for doing symbolic computation. The first attempt at this was differentiation of algebraic expressions. This initial experiment produced a list of language requirements, most notably was recursion and conditional expressions. At the time, not even FORTRAN (the only high-level language in existence) had these functions.

It was at the 1956 Dartmouth Summer Research Project on Artificial Intelligence that John McCarthy first developed the basics behind Lisp. His motivation was to develop a list processing language for Artificial Intelligence. By 1965 the primary dialect of Lisp was created (version 1.5). By 1970 special-purpose computers known as Lisp Machines, were designed to run Lisp programs. 1980 was the year that object-oriented concepts were integrated into the language. By 1986, the X3J13 group formed to produce a draft for ANSI Common Lisp standard. Finally in 1992, X3J13 group published the American National Standard for Common Lisp. Lisp has the following significant features:

- Atoms & Lists: Lisp uses two different types of data structures, atoms and lists. *Atoms* are similar to identifiers, but can also be numeric constants. *Lists* can be lists of atoms, lists, or any combination of the two
- Functional Programming Style: all computation is performed by applying functions to arguments. Variable declarations are rarely used.

- Uniform Representation of Data and Code: example: the list `(A B C D)`. It is a list of four elements (interpreted as data). It is also the application of the function named `A` to the three parameters `B`, `C`, and `D` (interpreted as code)
- Reliance on Recursion: a strong reliance on recursion has allowed Lisp to be successful in many areas, including Artificial Intelligence.
- Garbage Collection: Lisp has built-in garbage collection, so programmers do not need to explicitly free dynamically allocated memory.

Lisp totally dominated Artificial Intelligence applications for a quarter of a century, and is still the most widely used language for AI. In addition to its success in AI, Lisp pioneered the process of Functional Programming. Many programming language researchers believe that functional programming is a much better approach to software development, than the use of Imperative Languages (Pascal, C++, etc). Below is a short list of the areas where Lisp has been used:

- Artificial Intelligence
- Air Defense Systems
- Implementation of Real-Time, embedded Knowledge-Based Systems
- List Handling and Processing
- Tree Traversal (Breath/Depth First Search)
- Educational Purposes (Functional Style Programming)

5.2.12 ML

ML (standing for "Meta-Language") is a functional programming language developed in the early 1980s at Edinburgh University. Today there are several languages in the ML family; the most popular are SML (Standard ML) and Ocaml. [67]

Standard ML of New Jersey (abbreviated SML/NJ) is a compiler for the Standard ML '97 programming language with associated libraries, tools, and documentation. SML/NJ is free, open source software. Moscow ML is a light-weight implementation of Standard ML (SML), a strict functional language widely used in teaching and research. Version 2.00 implements the full SML language, including SML Modules, and much of the SML Basis Library. Poly/ML is a full implementation of Standard ML available as open-source.

Objective CAML, also known as Ocaml or O'Caml for short (or some other alternative spelling), is an advanced programming language based on the ML family. To the functional and imperative features of Standard ML, it adds object-oriented concepts.

Ocaml provides both a bytecode compiler and a native code compiler, and the latter has been ported to a large number of platforms. The code generated by the native compiler is typically comparable to C/C++ in speed. [67]

5.2.13 MODULA

In the mid 1970's, after the language Pascal was designed, Niklaus Wirth was experimenting with concurrency that led to the design of Modula. Modula was never released and its development was discontinued after its publication. Wirth then built a language that was meant to be the single language for the new computer system called

Lilith. Even though the computer was never a success, his new language Modula-2 was released in 1980.

Modula-2 was designed based on Pascal and Modula but its improvements over Pascal included modules, low level features, coroutines, and syntactic features.

- Modules: a tool for expressing the relations between major parts of programs and provide support for abstract data types.
- Low Level Features: small language that can be implemented on a wide variety of microcomputers contains facilities for high level and low level programming.
- Coroutines: used for embedded systems that require concurrency without the overhead of large operating systems or large languages.
- Syntactic Features: has a small vocabulary and consists of few sentence structures, contains simple and consistent rules of syntax that makes it easy to learn.

Modula-2 is a simple but yet a powerful language that is suitable for a wide range of applications.

- Systems Programming
- Concurrent Programming
- Embedded Systems
- Software Engineering
- Education

5.2.14 PASCAL

The Pascal programming language was originally developed by Niklaus Wirth, a member of the International Federation of Information Processing (IFIP) Working Group 2.1. Professor Niklaus Wirth developed Pascal to provide features that were lacking in other languages of the time. His principal objectives for Pascal were for the language to be efficient to implement and run, allow for the development of well-structured and well-organized programs, and to serve as a vehicle for the teaching of the important concepts of computer programming. Pascal, which was named after the mathematician Blaise Pascal, is a direct descendent from ALGOL 60, which Wirth helped develop. Pascal also draws programming components from ALGOL 68 and ALGOL-W. The original published definition for the Pascal language appeared in 1971 with latter revisions published in 1973. It was designed to teach programming techniques and topics to college students and was the language of choice to do so from the late 1960's to the late 1980's. [67]

Pascal contains some significant language features that allow it to used as a powerful learning tool in introducing structured programming techniques to students:

- Built in Data Types: Pascal contains its own built in data types of Integer, Real, Character, and Boolean.
- User defined Data Types: Has the ability to define scalar types as well as subranges of those data types.
- Provides a defined set of Data Structures: These data structures include Arrays, Records, Files and Sets.

- Has a strong data typing element: Pascal compliers can diagnose an incompatible assignment of one type to a variable to another type.
- Supports Structured Programming: This is accomplished through the use of subprograms called procedures and functions.
- Simplicity and Expressiveness: Because the language is simple and expressive in nature it allows for effective teaching of computer programming techniques.

The Prime area of application that Pascal entails is the learning environment. This language was not really developed to be used for anything other than teaching students the basics of programming. After all it was originally developed for this purpose. In the early 1970's to the early 1990's Pascal was the language of choice for most major colleges and universities for teaching college level programming techniques. Now with the growing popularity of Object Orient Programming Pascal has taken a back seat to other languages such as C++ and Visual Basic.

5.2.15 PROLOG

Prolog (PROgramming LOGic) rose within the realm of Artificial Intelligence (AI). It originally became popular with AI researchers, who know more about "what" than "how" intelligent behavior is achieved. The philosophy behind it deals with the logical and declarative aspects. Prolog represents a fundamentally new approach to computing and became a serious competitor to LISP. [67]

Prolog is a rich collection of data structures in the language and human reasoning, and a powerful notation for encoding end-user applications. It has its logical and declarative aspects, interpretive nature, compactness, and inherent modularity.

- Intelligent Systems: programs that perform useful tasks by utilizing artificial intelligence techniques.
- Expert Systems: intelligent systems which reproduce decision-making at the level of a human expert.
- Natural Language Systems: which can analyze and respond to statements made in ordinary language as opposed to approved keywords or menu selections.
- Relational Database Systems

Prolog is the highest level general-purpose language widely used today. It is taught with a strong declarative emphasis on thinking of the logical relations between objects or entities relevant to a given problem, rather than on procedural steps necessary to solve it. The system decides the way to solve the problem, including the sequences of instructions that the computer must go through to solve it. It is easier to say what the programmers want done and leave it to the computer to do it. Since a major criterion in the commercial world today is speed of performance, Prolog is an ideal prototyping language. Its concept makes use of parallel architectures. It solves problems by searching a knowledge base (or more correctly a database) that would be greatly improved if several processors were made to search different parts of the database.

5.2.16 SMALLTALK

The Learning Research Group at Xerox PARC designed a language to support Alan Kay's programming paradigm. This led to the Smalltalk-72 software. After experiments were performed on Smalltalk-72, a sequence of languages ending in Smalltalk-80 were developed. Smalltalk has the following significant language features: [67]

- Object-Oriented: Smalltalk is a language in which reusable objects exchange messages.
- Graphical Programming Environment: First look at cut/copy/paste in programming language for most people.
- Versatile: Has many applications and uses.
- Graphic primitives and drawing programs: Supports quickly and easily created graphics.

The demand for Smalltalk programmers is growing in areas where the telecommunications industry is strong.

- Business Information System
  - Chosen because of Technical merit and flexibility
  - Well suited for large projects
- Embedded in an oscilloscope
- Manages the telephone system of an entire country
- Batch programs for large mainframes

5.2.17 SCHEME

Scheme started as an experiment in programming language design by challenging some fundamental design assumptions. It emerged from MIT in the mid-1970's. It is a dialect of the Lisp Programming Language invented by Guy Lewis Steele Jr. and Gerald Jay Sussman. Originally called Schemer, it was shortened to Scheme because of a 6-character limitation on file names. Scheme is a small, exceptionally clean language that is fun to use. The language was designed to have very few, regular constructs which compose well to support a variety of programming styles including functional, object-oriented, and imperative. [67]

Scheme has lexical scoping, uniform evaluation rules, and uniform treatment of data types. Scheme does not have the concept of a pointer, uninitialized variables, specialized looping constructs, or explicit storage management. In Scheme, all data types are equal. What one can do to one data type, one can do to all data types. There are seven kinds of expressions: Constant, Variable reference, Procedure creation, Procedure application, Conditional, Assignment, and Sequence. Scheme also has the usual assortment of data types: Characters, Strings, Arrays, Lists, Numbers, Functions (also called procedures), Boolean, Ports, and Symbols. Numbers are especially interesting in that an integer is a rational and a real is a complex. Scheme requires no looping constructs. Any function that calls itself in the "tail" position is just a loop. Scheme has several important advantages. It is elegantly simple in that regular structure and trivial syntax avoids "special case" confusion. Its expressiveness means that one spends little time trying to work around the language--it lets users concentrate on what they want to say rather than on how to say it. Its support of a variety of styles (including object-oriented) allows users to better match their solution style to the style of the problems to be solved. Its formal underpinnings make reasoning about programs much easier. Its abstractive power makes it easy to separate system specific optimizations from reusable code. Its composability makes it easy to construct systems from well-tested components.

Scheme is currently gaining favor as a first programming language in universities and is used in industry by such companies as DEC, TI, Tektronix, HP, and Sun.

5.3 Data Collection

In chapter four, the methods of how to quantify intrinsic factors and extrinsic factors have been defined. In this section, how to collect data based on these rules will be discussed.

Data collection is a hard and time-consuming job. Because there is no database for most of the questions, they have to be answered from the very beginning. Due to limited resources, the programming language trends group could only do random surveys and use survey results to answer the questions. During the past year, several surveys have been done. By doing these surveys and analyzing each programming language, a lot of data have been collected for both intrinsic factors and extrinsic factors. To store all of these data, a data warehouse is established in software engineering lab in New Jersey Institute of Technology. For the details, please visit http://www.cs.njit.edu/techwatch and http://swlab.njit.edu/techwatch.

By analyzing the data in this data warehouse, good understanding could be gained in historical trends of each programming language. The whole empirical study will be based on this data warehouse.

5.3.1 Data Collection for Intrinsic Factors

To collect data for intrinsic factors, the programming language trends research group uses the textbook for the first version of each programming language and tries to evaluate intrinsic factors based on these textbooks. All of these intrinsic factors have been considered. One will try to go over all features of a programming language to check if it matches these factors, and then give it a score. Please check table 5-1 for details.

Table 5.1 Scores of Intrinsic Factors

	I1	I2	I3	I4	I5	I6	I7	I8	I9	I10	I11
ADA	85	93	90	90	70	10	55	80	90	70	15
ALGOL	43	87	40	40	33	70	80	70	30	90	45
APL	7	7	40	40	33	30	80	70	10	20	10
BASIC	10	53	40	40	33	95	90	80	30	60	30
C	63	67	30	40	33	37	85	80	90	60	30
C++	83	73	70	90	67	30	75	80	90	70	25
COBOL	15	87	40	40	30	37	85	70	10	50	15
EIFFEL	47	73	90	90	67	33	70	70	60	60	10
FORTRAN	34	86	40	50	33	77	80	70	50	60	95
JAVA	76	66	90	90	67	17	60	90	90	70	10
LISP	39	27	67	40	70	73	90	70	30	90	10
ML	53	73	80	73	30	73	90	70	60	25	10
MODULA	18	87	40	40	33	67	80	70	60	30	20
PASCAL	25	47	70	60	50	73	85	80	80	50	50
PROLOG	15	27	40	37	80	87	80	70	30	90	10
SCHEME	32	73	73	80	80	83	85	70	30	30	10
SMALLTALK	78	80	80	90	67	20	75	80	80	50	10

I1:	Generality
I2:	Orthoganality
I3:	Reliability
I4:	Maintainability
I5:	Efficiency
I6:	Simplicity
I7:	Implementability
I8:	Machine Independence
I9:	Extensibility
I10:	Expressiveness
I11:	Influence/Impact

5.3.2 Data Collection for Extrinsic Factors

In order to collect data for extrinsic factors, the programming language trends group was divided by factors instead of programming languages. The reason is, for each extrinsic factor (question), each person should concentrate on one field (such as institutions, industries, governments, etc) and collecting data for all languages in this particular field.

Surveys have been done for each field of extrinsic factors in 1993, 1998 and 2003. Please check http://swlab.njit.edu/techwatch/survey.asp and see the survey for grassroots support. The other surveys are similar to the previous one, and the only difference is that they are in different fields.

CHAPTER 6

SURVEY RESULTS

This chapter will discuss the raw data that have been collected in the data warehouse. The programming language trends group is very interested in the survey results they got and would like to discuss some of the questions. To check complete survey results for all questions, please visit the website http://swlab.njit.edu/techwach.

6.1 Survey Results for Grassroots Support

The first question for grassroots support is: "How many people consider this Language as their primary programming Language?"

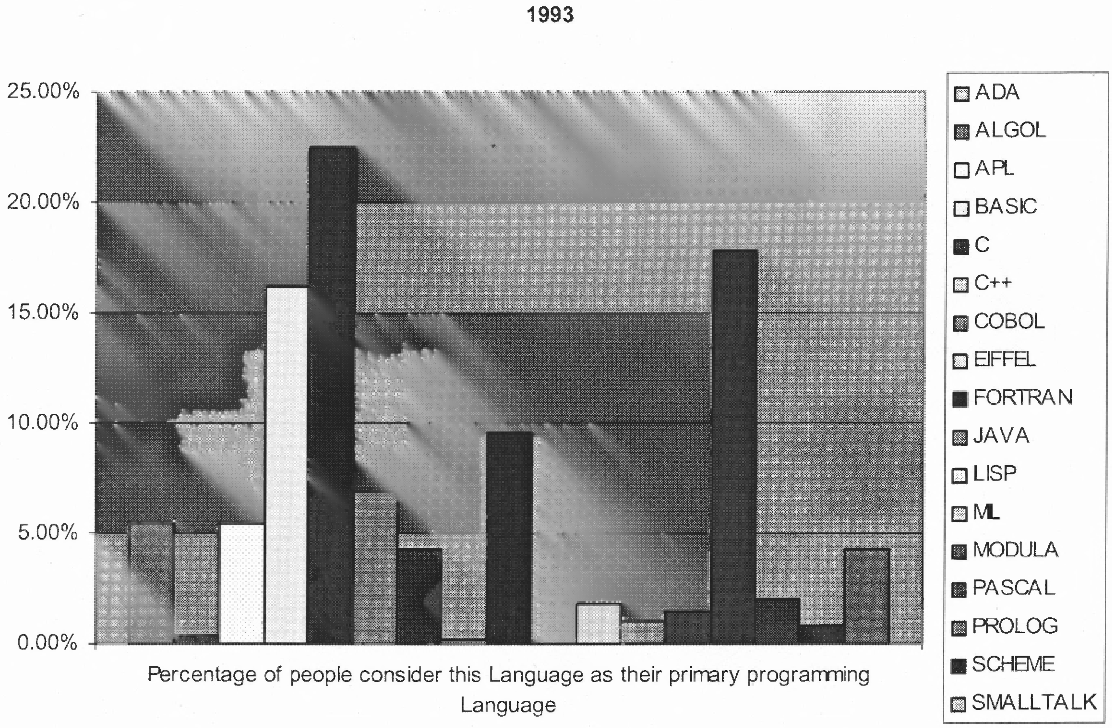
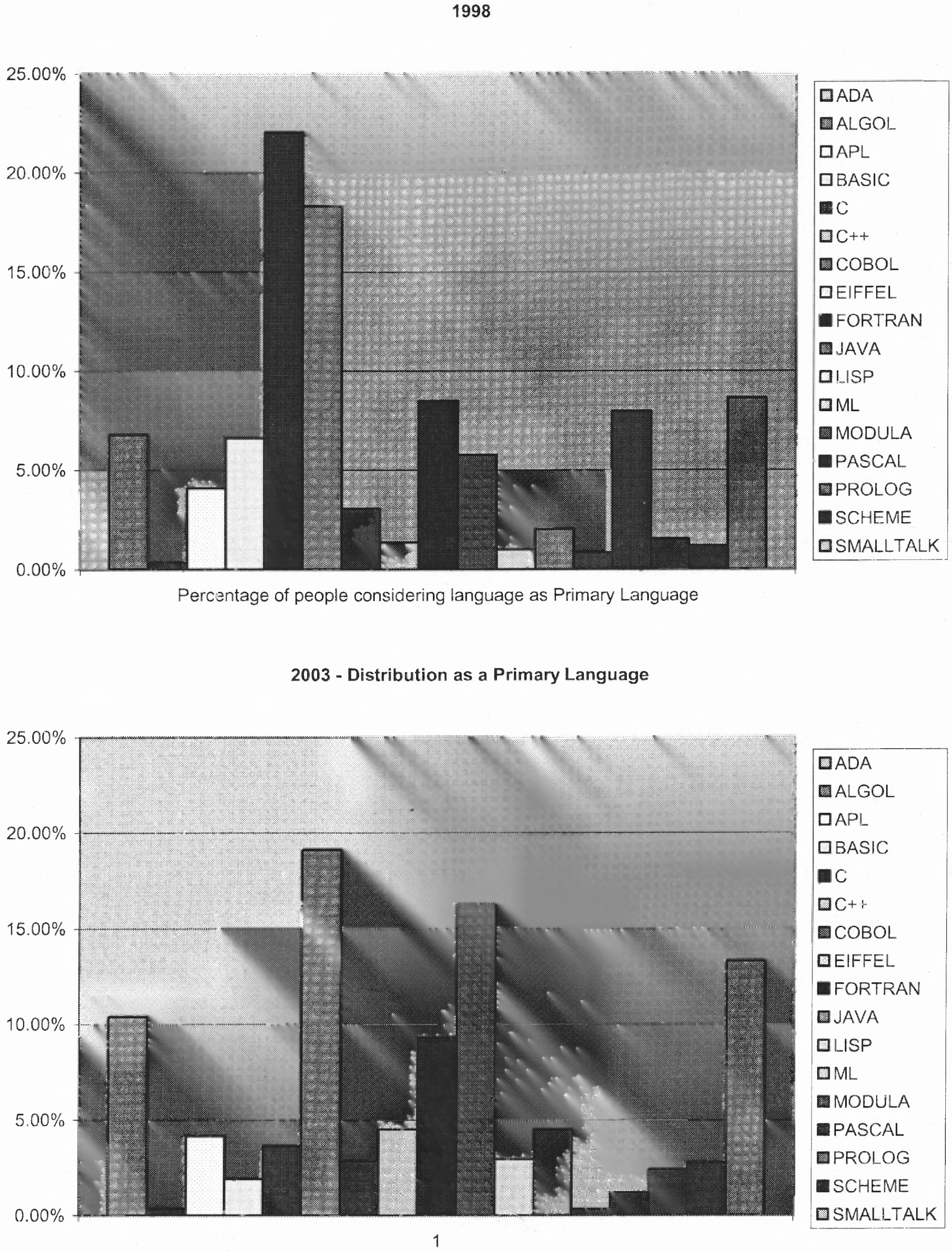


Figure 6.1 How many people consider this language as primary one in 1993, 1998, and 2003.



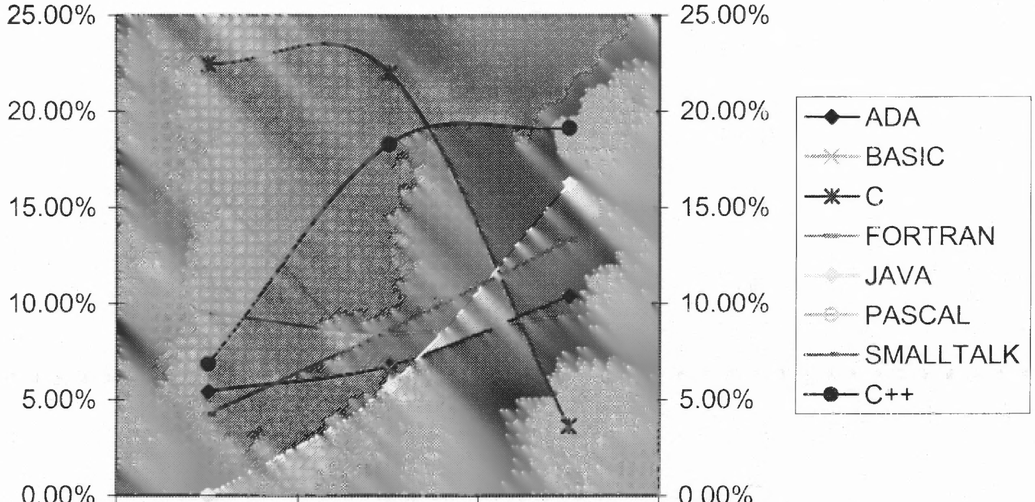
1998

2003 - Distribution as a Primary Language

Figure 6.1 How many people consider this language as primary language in 1993, 1998, and 2003.(Continued)

Figure 6.1 shows what happened in 1993, 1998, and 2003. (Notice: JAVA was created in 1995, so 0 is assigned to JAVA in 1993.) From the graphs above, the 5 most popular languages in 1993 are: C (22.47%), PASCAL (17.81%), BASIC (16.19%), FORTRAN (9.51%), C++ (6.88%). The 5 most popular languages in 1998 are: C (22.03%), C++ (18.31%), SMALLTALK (8.64%), FORTRAN (8.47%), PASCAL (7.79%). The 5 most popular languages in 2003 are: C++ (19.12%), JAVA (16.26%), SMALLTALK (13.32%), ADA (10.38%), FORTRAN (9.34%).

The following graph will show the trends of most popular programming languages from 1993 to 2003.



	1993	1998	2003
ADA	5.47%	6.78%	10.38%
BASIC	16.19%	6.61%	1.90%
C	22.47%	22.03%	3.63%
FORTRAN	9.51%	8.47%	9.34%
JAVA	0.00%	5.76%	16.26%
PASCAL	17.81%	7.97%	1.21%
SMALLTALK	4.25%	8.64%	13.32%
C++	6.88%	18.31%	19.12%

Figure 6.2 Trends of most popular programming languages from 1993 to 2003.

Another interesting question for grassroots support is: "How many people know this Language". Figure 6.3 shows what happened in 1993, 1998, and 2003.

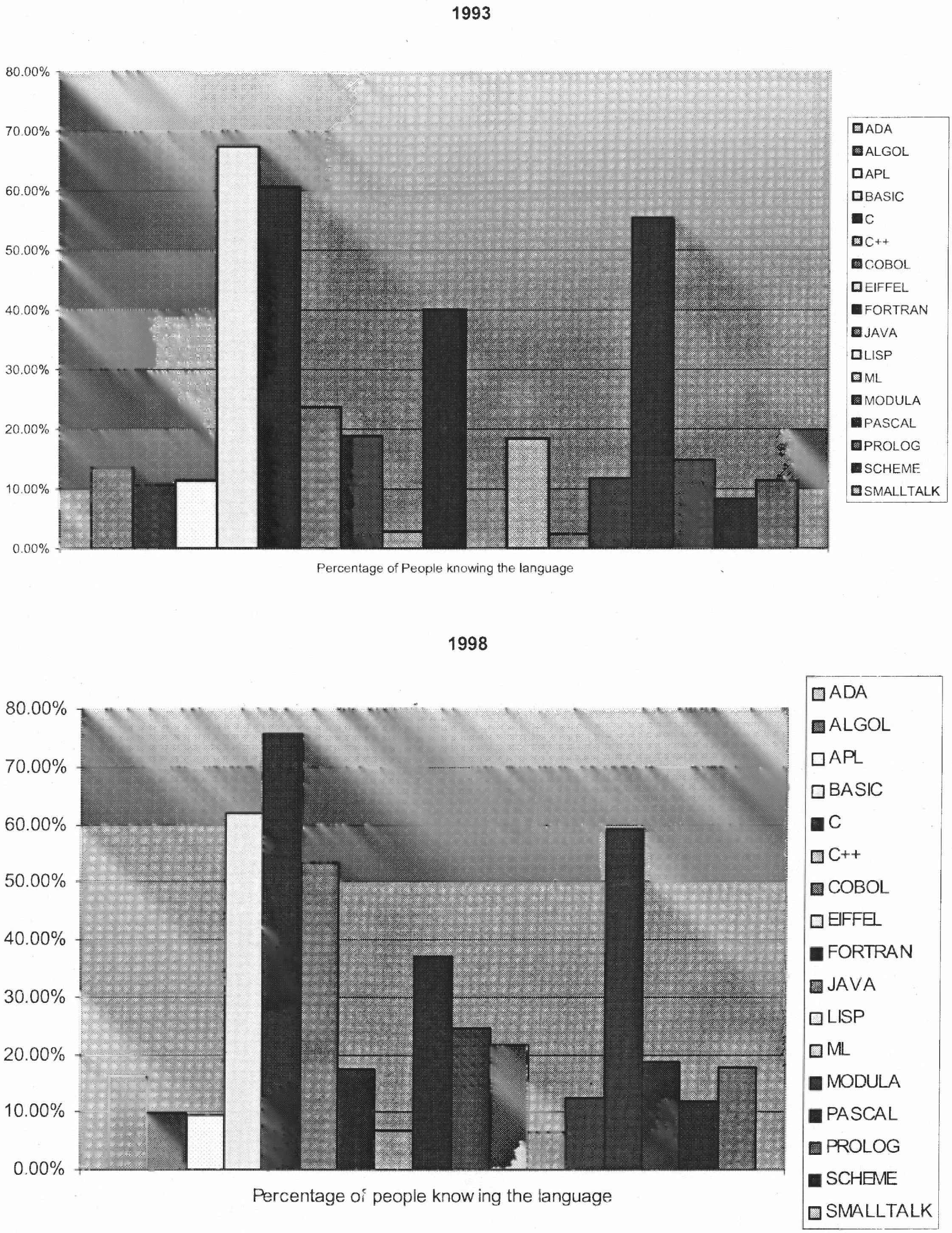


Figure 6.3 How many people know this language in 1993, 1998, and 2003.

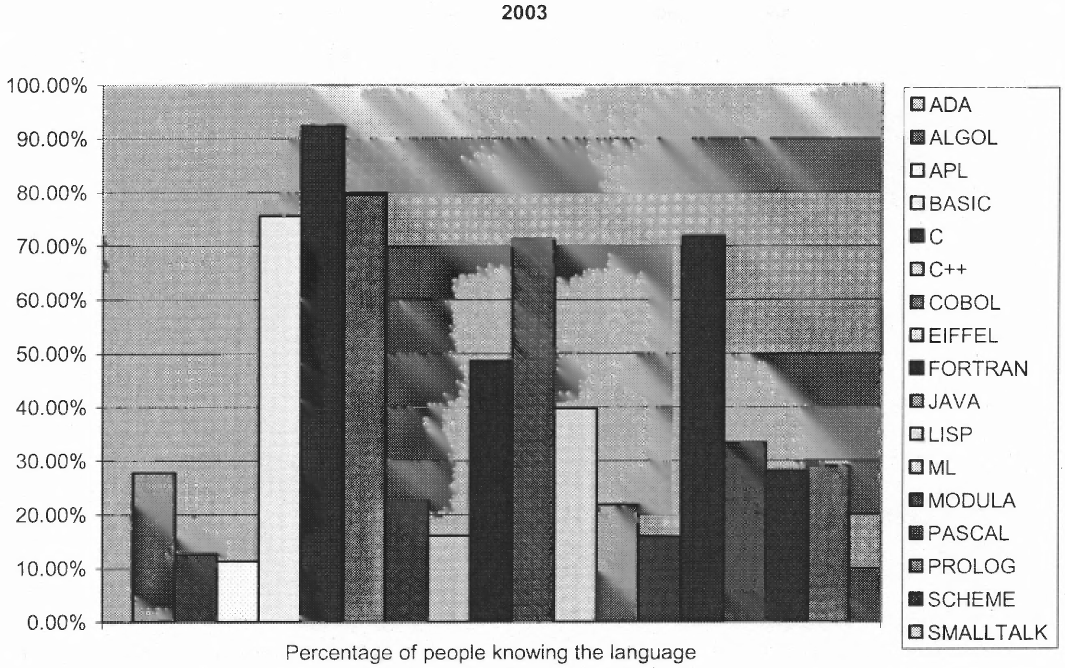
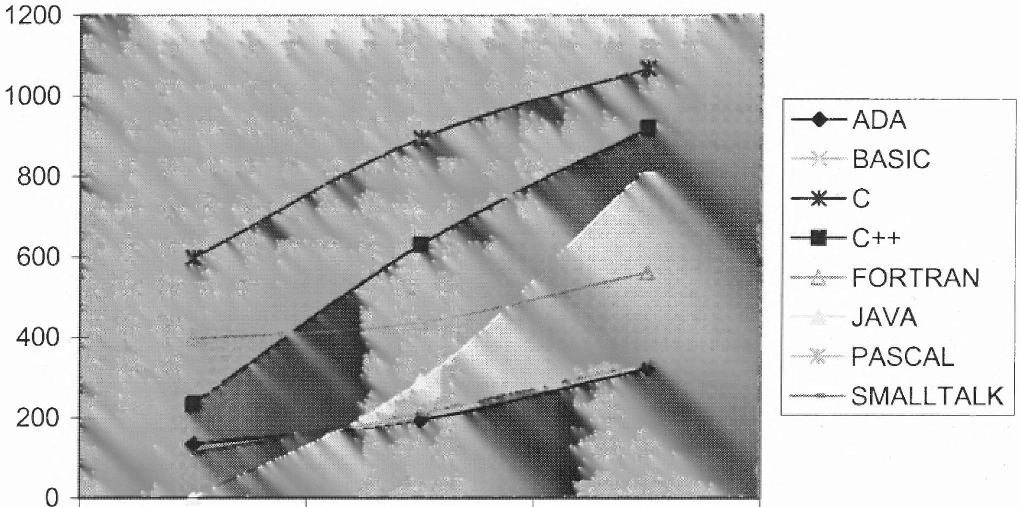


Figure 6.3 How many people know this language in 1993, 1998, and 2003.(Continued)

From the graph above, the top 5 programming languages people knew in 1993 are: BASIC (67.41%), C (60.35%), PASCAL (55.47%), FORTRAN (40.08%), C++ (23.68%). The top 5 programming languages people knew in 1998 are: C (75.93%), BASIC (61.86%), PASCAL (59.32%), C++ (53.39%), FORTRAN (36.95%). The top 5 programming languages people know in 2003 are: C (92.39%), C++ (79.67%), BASIC (75.61%), PASCAL (71.97%), JAVA (71.28%).

The following graph shows the trends of most-people-known programming languages from 1993 to 2003.



	1993	1998	2003
ADA	134	194	322
BASIC	666	730	874
C	598	896	1068
C++	234	630	921
FORTRAN	396	436	562
JAVA	0	290	824
PASCAL	548	700	832
SMALLTALK	112	211	336

Figure 6.4 Trends of most-people-known languages from 1993 to 2003.

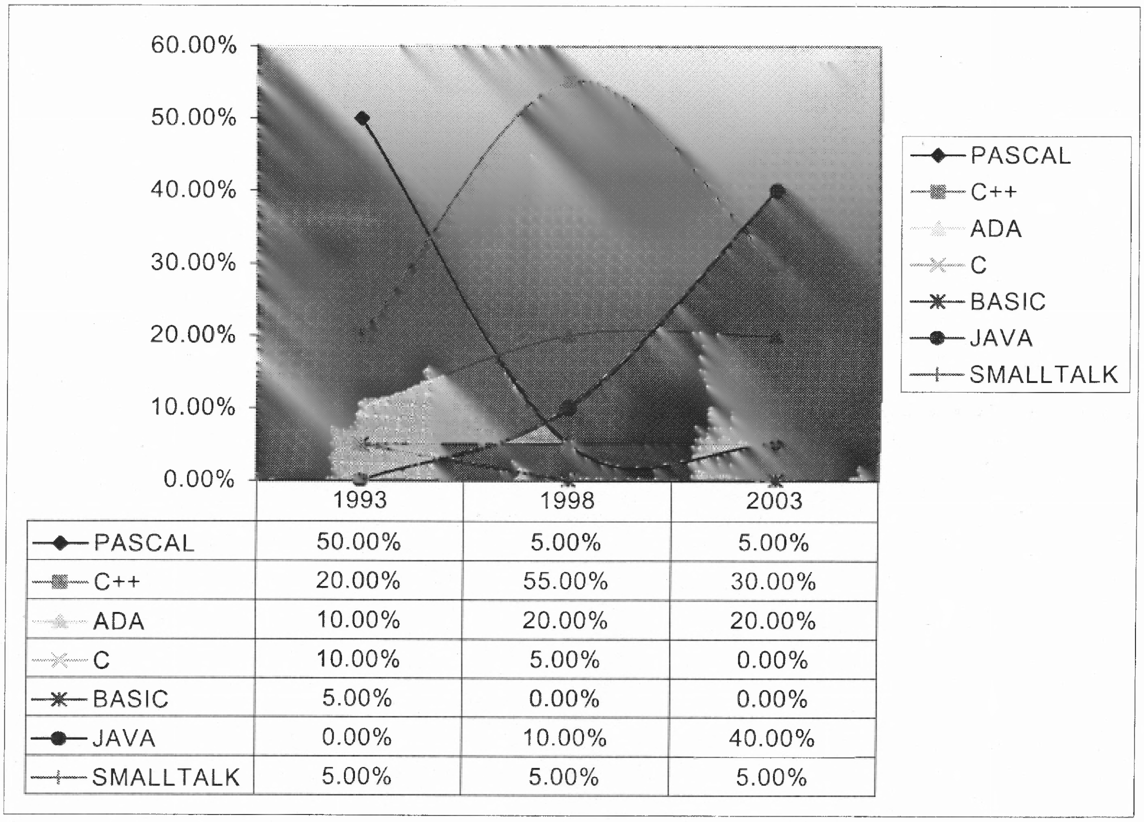
From Figures 6.2 and 6.4, it is clear that the primary programming languages changed dramatically during these ten years. The object-oriented languages get more advantages than the other languages and become more popular. For "old-styled" languages, although they are not considered as primary language any more, there are still large populations who know those languages.

For trends of other factors in grassroots support, please check the website for more details.

6.2 Survey Results for Institutional Support

The question for institutional support is: "How many institutions use this language for their introductory programming language courses?" Please check what happened in 1993, 1998, and 2003.

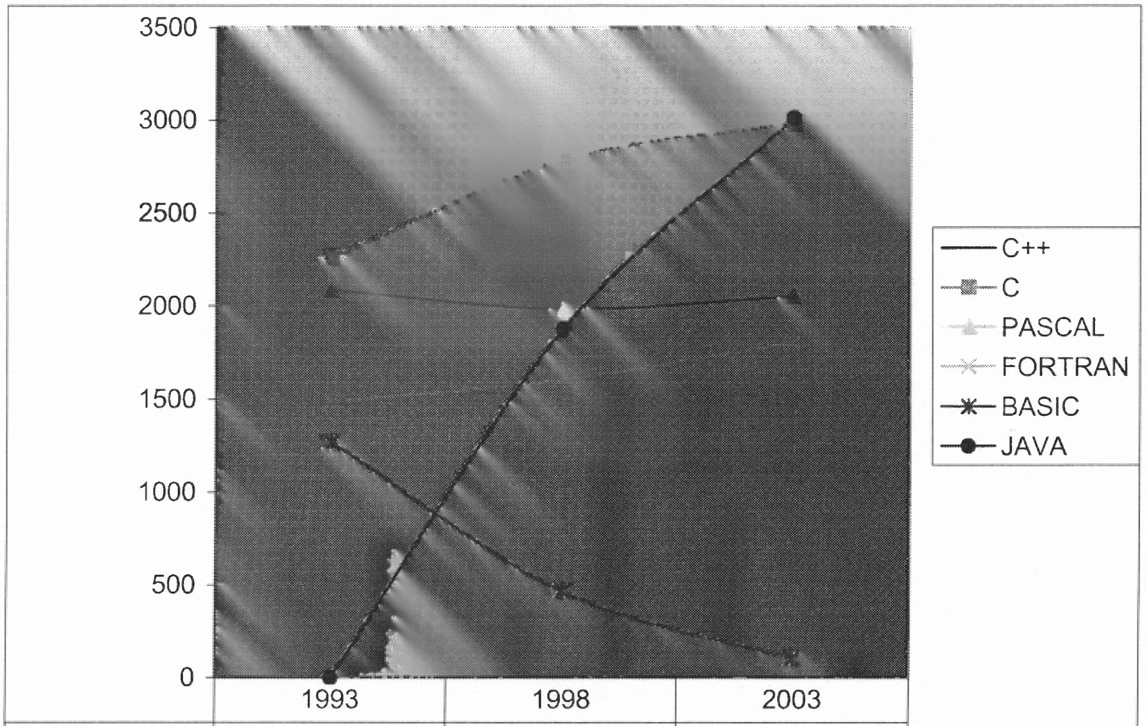
In 1993, Pascal has been used extensively than other languages even though C++ has been used to some extent. Ada also has been used in 1998 and 2003. But in 1998 C++ has been used more than other languages. In 2003 JAVA has taken up the position since it become very popular in recent years.



	1993	1998	2003
◆ PASCAL	50.00%	5.00%	5.00%
■ C++	20.00%	55.00%	30.00%
▲ ADA	10.00%	20.00%	20.00%
× C	10.00%	5.00%	0.00%
✱ BASIC	5.00%	0.00%	0.00%
● JAVA	0.00%	10.00%	40.00%
+ SMALLTALK	5.00%	5.00%	5.00%

Figure 6.5 Numbers of institutions use this language as introductory language from 1993 to 2003.

Figure 6.6 shows how many students use this language for any of their courses. Students used Pascal, C and C++ extensively in the year 1993. In 1998, JAVA had considerably improved its popularity among students. In 2003 JAVA has been improved as well and becomes the most preferred language. C/C++ and FORTRAN are almost the same for all the three years taken into consideration. For more survey results in institutional support, please check the website.

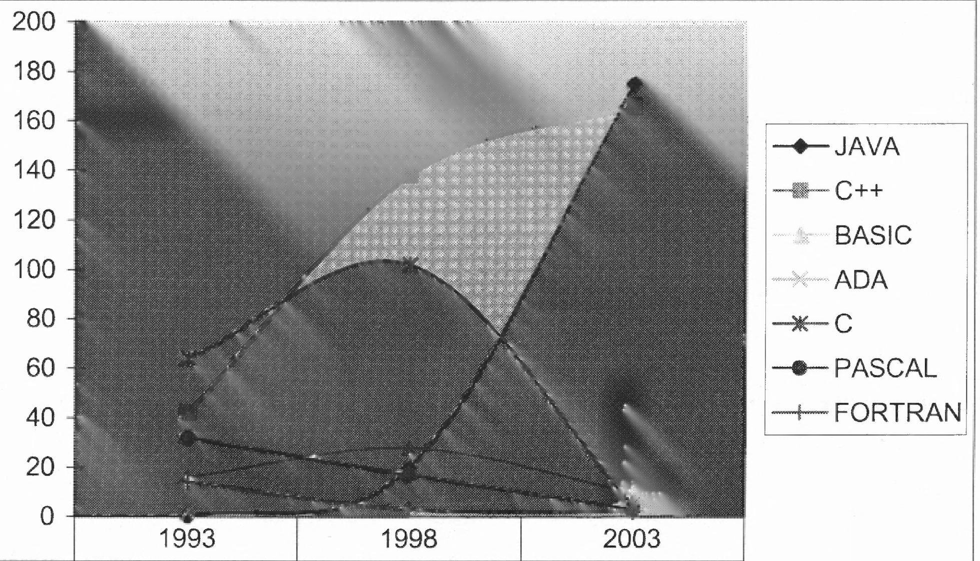


	1993	1998	2003
— C++	2261	2786	2985
■ C	2261	2786	2985
▲ PASCAL	2086	1985	2052
× FORTRAN	1486	1604	1804
✱ BASIC	1268	468	102
● JAVA	0	1876	3012

Figure 6.6 Numbers of students use this language for any of their courses from 1993 to 2003.

6.3 Survey Results for Industrial Support

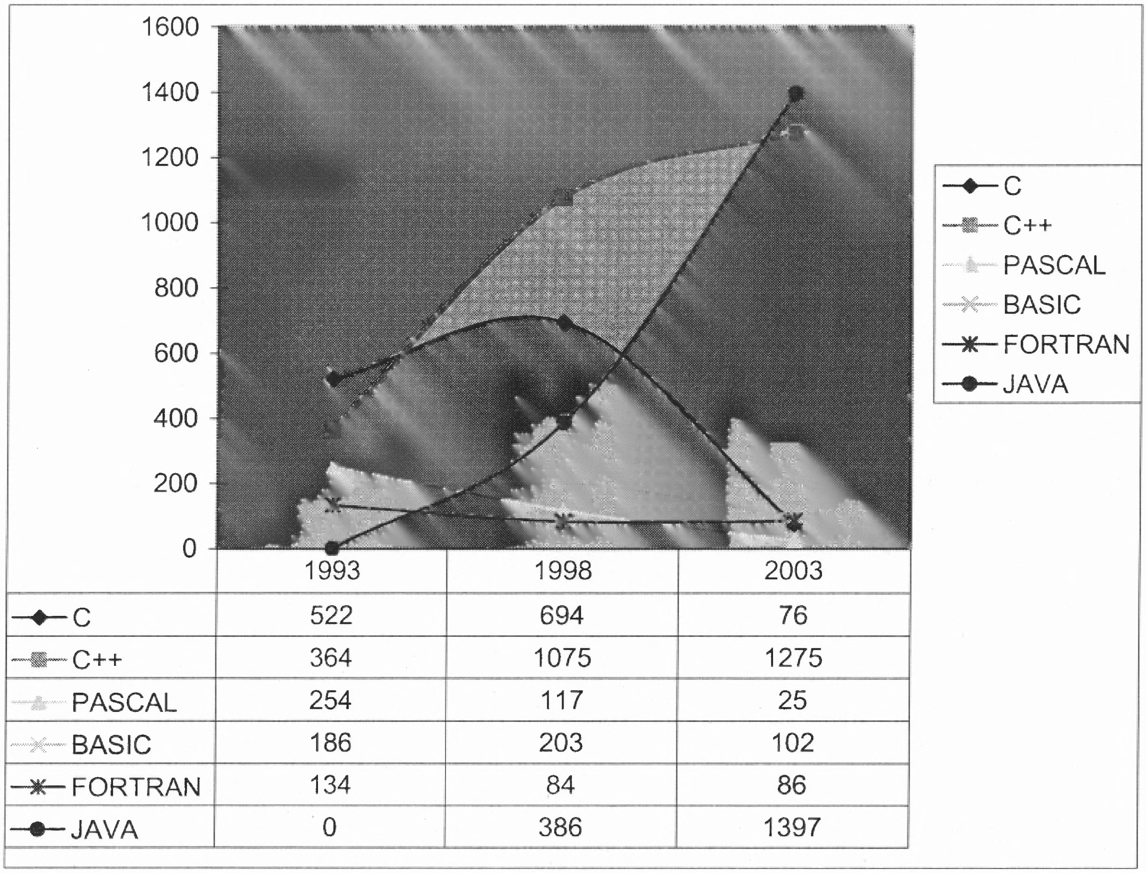
This section will watch the trends of programming languages in industry. How many companies use this language as primary programming language to develop products? The graph below shows that in year 1993 there were more companies (around 36% of them) using C for their products development. Next in that was C++ with around 24%. In the year 1998, C++ was used in up to 48% of the companies and C was in around 31% of the companies. It is clear that in 1998 the other languages did not make a significant impact in the development of products in companies. In 2003 almost half of the companies used JAVA and C++ is used by around 44% of the companies.



	1993	1998	2003
◆ JAVA	0	20	175
■ C++	42	138	166
▲ BASIC	16	28	10
× ADA	2	5	8
✳ C	64	102	5
● PASCAL	32	17	3
+ FORTRAN	14	3	2

Figure 6.7 Numbers of companies use this language as primary language from 1993 to 2003.

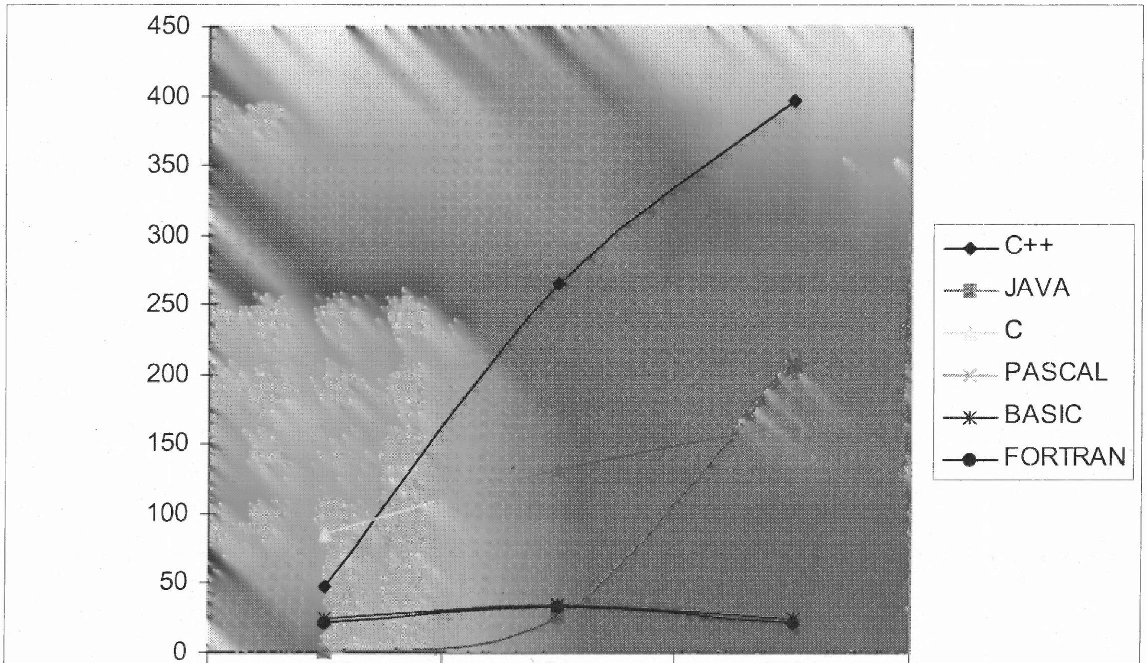
Figure 6.8 shows how many developers consider this language as their primary language. In 1993, developers felt comfortable with C that 34% of the developers used. The second position was C++ that was preferred at around 32%. Pascal was in third place with 16%. Around 12% of the developers preferred BASIC. In 1998 around 40% of the developers preferred C++ and 26% of them preferred C. But in 2003 the usage of JAVA dramatically increased among the programmers and around 45% of the programmers used JAVA. C++ remains the second while approximately 41% of programmers consider it as their primary language.



	1993	1998	2003
◆ C	522	694	76
■ C++	364	1075	1275
▲ PASCAL	254	117	25
× BASIC	186	203	102
✱ FORTRAN	134	84	86
● JAVA	0	386	1397

Figure 6.8 Numbers of developers use this language as primary language from 1993 to 2003.

How many commercial applications are developed using this language? In the year of 1993, a large number of applications were developed in C (38%). C++ and Pascal also played a considerable part in developing the applications. BASIC and COBOL played a part in the development of various applications as shown in the graph. In the year of 1998, C++ played a major role in the development of applications around half of the applications were developed in this language. Around 25% of the applications used C. In 2003, C++ continues to be in the top, while JAVA grows very fast in recent period.

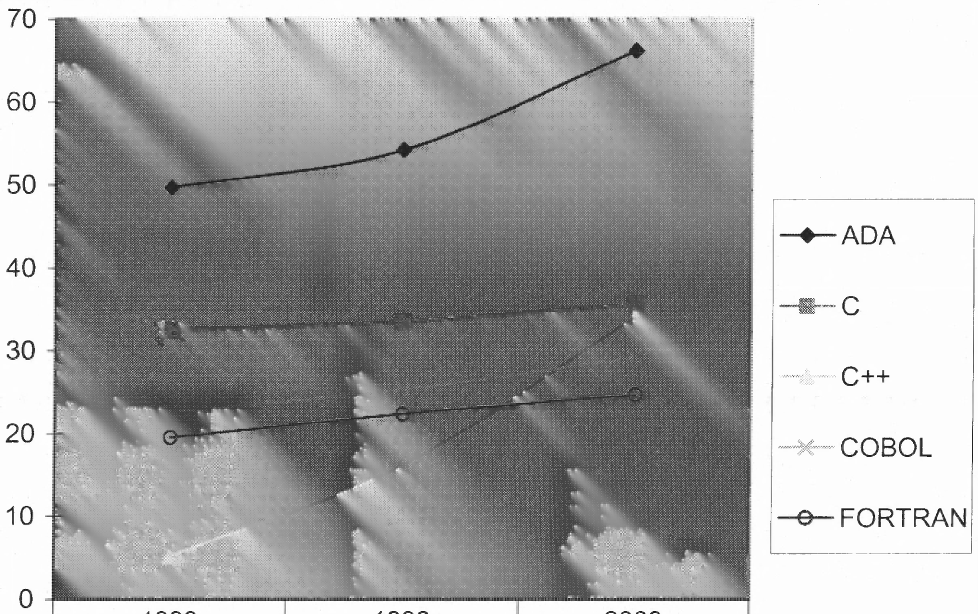


	1993	1998	2003
◆ C++	48	265	397
■ JAVA	0	26	207
▲ C	85	132	164
× PASCAL	34	43	25
✳ BASIC	24	35	25
● FORTRAN	21	34	21

Figure 6.9 Numbers of commercial applications developed by this language from 1993 to 2003.

6.4 Survey Results for Governmental Support

How much code is written by government in this language? As in the graph, the maximum number of code is written in the language ADA with 36.78% for the year 1993, followed by 24.05% for C. 16.76% of code are written in COBOL, while 14.47% are written in FORTRAN in 1993. In the year 1998, ADA still had the maximum of 33.07%, C with 20.44% followed by COBOL with 15.45% and FORTRAN with 13.67%. Also in the year 2003 ADA has 30.74%, C with 16.53, C++ with 15.84%, COBOL with 13.56% and FORTRAN with 11.47%. Figure 6.10 shows the graph for all the three years put together for the number of lines of code written for a particular language.

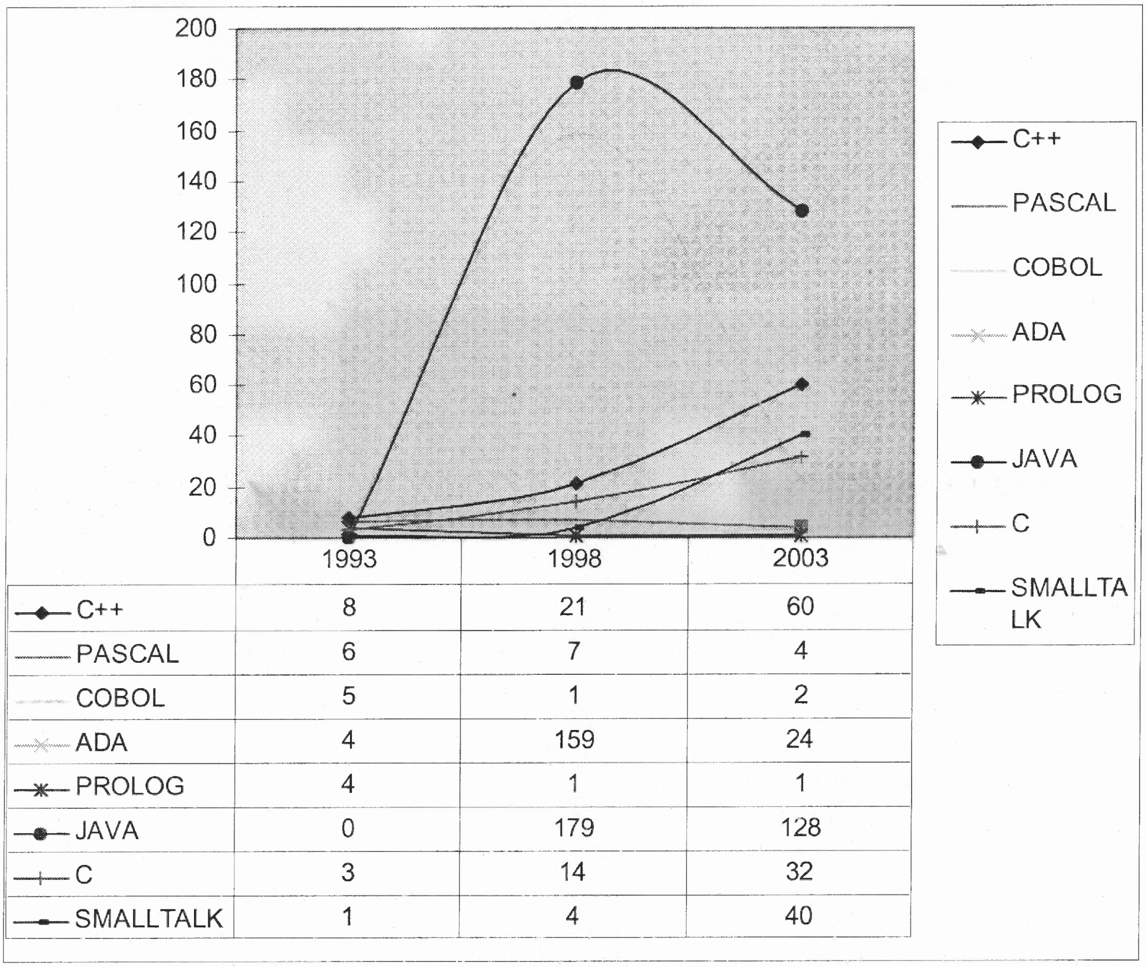


	1993	1998	2003
ADA	49.7	54.2	66.2
C	32.5	33.5	35.6
C++	5.15	16.15	34.1
COBOL	22.65	25.32	29.2
FORTRAN	19.55	22.4	24.7

Figure 6.10 How much code is written by government in this language from 1993 to 2003.

6.5 Survey Results for Organizational Support

Figure 6.11 shows the graphs for the number of conferences in the three years. C++ is the largest at 18.6% in the year 1993. PASCAL is at approximately 14%. COBOL comes next to PASCAL at 11.63%. Next is ADA with approximately 9.5% of the conferences. In the year 1998, there has been a great increase in the conferences in JAVA to 45% followed by ADA with nearly 40% of the conferences. In 2003, JAVA has the highest number of conferences with as many as 40%. Next is C++ with nearly 19%. The next is Small talk with approximately 12%.



	1993	1998	2003
C++	8	21	60
PASCAL	6	7	4
COBOL	5	1	2
ADA	4	159	24
PROLOG	4	1	1
JAVA	0	179	128
C	3	14	32
SMALLTALK	1	4	40

Figure 6.11 Numbers of conferences for each language from 1993 to 2003.

6.6 Survey Results for Technology Support

For technical support, no graph will be drawn here for each question because there are not too many changes during the time and the number change is small.

In the survey, C and C++ consistently have the higher percentage of compilers than other languages. Around 22% of the compilers were C and C++ compilers. The number of debuggers for C and C++ are also the highest among all languages. BASIC, FORTRAN and PASCAL come after C and C++. After JAVA was introduced in 1995, SUN is the major provider for compiler, interpreter, and debugger. The other companies generally will use SUN's technology and provide some CASE tools.

It is notable that C/C++ have much more third-parties library than the other languages. JAVA includes a lot of libraries as its own language features while the other language does not. For operating systems, almost every OS will support all of these languages. JAVA has more advantage in networking support while C/C++ get more support in database fields.

CHAPTER 7

DATA ANALYSIS & MODEL CONSTRUCTION

In the previous chapters, the following questions have been discussed: how to find out the relevant factors, how to quantify those relevant factors, and how to collect data for them. After the data warehouse has been established, the new questions are: how to analyze these data, how to construct the proper statistics models that can be used to describe the history of programming languages, and how to extend the statistics models to predict the trends of programming languages.

7.1 Statistics Models

In this project, SAS statistic toolbox will be used to help describe historical programming language trends and predict the evolution of future trends. First, the data collected in the data warehouse will be analyzed to extract some descriptive properties to characterize the evolution of programming language over time. Second, infer on available data to predict the future trends of programming languages. Chapter seven will try to analyze data and construct the statistics model for historical and current trends. In chapter eight, the statistics models will be extended to predict future trends.

Regression models will be used to analyze the historical data. As an empirical modeling approach, regression uses polynomials as local approximations to the true input/output relationship. This empirical approach is often adequate for process improvement in an industrial setting.

In scientific applications there is usually relevant theory that allows us to make a mechanistic model. Often such models are linear or nonlinear in the unknown parameters. Nonlinear models are more difficult to fit, requiring iterative methods that start with an initial guess of the unknown parameters. Each iteration alters the current guess until the algorithm converges.

7.1.1 General Model

What is the general model that can be used to describe the past programming language trends and predict the future trends of programming languages? Let's check the following general model:

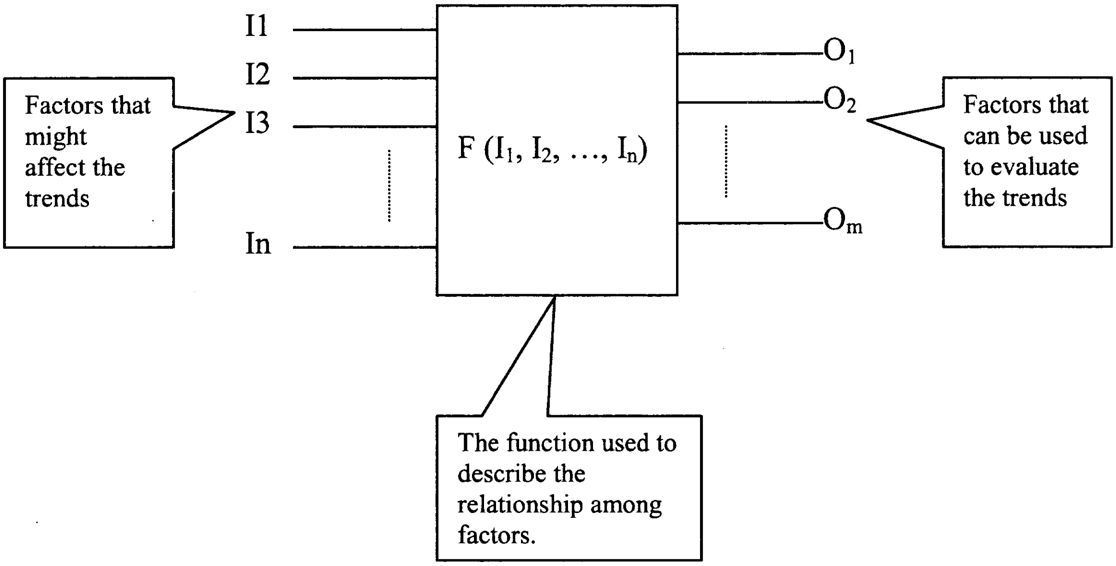

I1
I2
I3
In
Factors that might affect the trends
F (I1, I2, ..., In)
O1
O2
Om
Factors that can be used to evaluate the trends
The function used to describe the relationship among factors.

Figure 7.1 General models used to analyze data.

From the above general model, the following questions will be asked:

- What are the input factors?
- What are the output factors?
- What is F ( )?

In author's point of view, intrinsic factors and past extrinsic factors should be used as input factors, while current extrinsic factors should be used as output factors. The input factors and output factors are used to construct the statistics models. Section 7.2 will discuss how to analyze factors, and how to construct models will be discussed in section 7.3.

7.1.2 Possible Statistics Models

General models are used to describe the relationships between input and output factors. What kind of statistics models could be used to construct the general models?

It is well known that the general purpose of regression is to use the known relationship between independent and dependent variables to predict the future. In most applications, regression models are merely useful approximations. Reality is often so complicated that you cannot know what the true model is. One may have to choose a model more on the basis of what variables can be measured and what kinds of models can be estimated than on a rigorous theory that explains how the universe really works. However, even in cases where theory is lacking, a regression model may be an excellent predictor of the response if the model is carefully formulated from a large sample. In this project, regression is chosen to cons trust the model. The following are the possible regression models that could be used to describe programming language trends.

Linear Regression Model

Linear models are problems that take the form:

$$Y = X\beta + \varepsilon$$

where

- Y is an n by 1 vector of observations
- X is the n by p design matrix for the model
- β is a p by 1 vector of parameters
- ε is an n by 1 vector of random disturbances

Linear regression attempts to explain the relationship with a straight line fit to the data by the condition that the sum of the square residuals is as small as possible. One-way analysis of variance (ANOVA), two-way ANOVA, polynomial regression, and multiple linear regression are specific cases of the linear model.

Nonlinear Regression Model

The statistic toolbox has functions for fitting nonlinear models of the form:

$$Y = f(X, \beta) + \varepsilon$$

where

- Y is an n by 1 vector of observations
- f is any function of X and β
- X is an n by p matrix of input variables
- β is a p by 1 vector of unknown parameters to be estimated
- ε is an n by 1 vector of random disturbances

The goal of nonlinear regression is to fit a model to the data. The program finds the best-fit values of the variables in the model (perhaps rate constants, affinities, receptor number, etc.), which the researcher can interpret scientifically. Choosing a model is a scientific decision. One should base his/her choice on his/her understanding of chemistry or physiology (or genetics, etc.). The choice should not be based solely on the shape of the graph. Some programs automatically fit data to hundreds or thousands of equations and then present the equations that fit the data best.

7.2 Data Analysis

7.2.1 Factor Analysis

The factor analysis is used to do the startup research on raw data. The independence of the variables in groups is evaluated for further research. The relatively small number of latent factors proved that many variables are highly correlated and need either adjustment or combination, which make it necessary to do canonical analysis.

Factor analysis is a generic term for a family of statistical techniques concerned with the reduction of a set of observable variables in terms of a small number of latent factors. It has been developed primarily for analyzing relationships among a number of measurable entities (such as survey items or test scores). The underlying assumption of factor analysis is that there exist a number of unobserved latent variables (or "factors") that account for the correlations among observed variables, such that if the latent variables are partialled out or held constant, the partial correlations among observed variables all become zero. In other words, the latent factors determine the values of the observed variables. Each observed variable could be expressed as a weighted composite of a set of latent variables. The primary purpose of factor analysis is data reduction and summarization. Factor analysis has been widely used, especially in the behavioral sciences, to assess the construct validity of a test or a scale.

Once the input data are prepared for the analysis, it is necessary to decide on a factoring technique, that is, a method of extracting factors. There are a variety of different methods of factor extraction available in the PROC FACTOR procedure in SAS: principal component, principal factor, iterative principal factor, unweighted least-squares factor, maximum-likelihood factor, alpha factor, image analysis, and Harris component analysis. The two most commonly employed factor analytic techniques are principal component and principal factor analysis. The different FA techniques employ different criteria for extracting factors.

In this project, three sets of data (1993, 1998, and 2003), and 17 programming languages will be used as observations. So in final model, the construction of each factor is based on 51 observations.

Please check the following table. It will show the factor analysis for intrinsic factors.

Table 7.1 Factor Analysis for Intrinsic Factor Matrix

	Eigenvalue	Difference	Proportion	Cumulative
1	4.84558104	3.38822121	0.5719	0.5719
2	1.45735983	0.45464812	0.1720	0.7439
3	1.00271171	0.21366369	0.1183	0.8622
4	0.78904802	0.38881152	0.0931	0.9553
5	0.40023649	0.23567769	0.0472	1.0026
6	0.16455880	0.05255281	0.0194	1.0220
7	0.11200599	0.10849653	0.0132	1.0352
8	0.00350945	0.03766573	0.0004	1.0356
9	-.03415628	0.07557906	-0.0040	1.0316
10	-.10973533	0.04809012	-0.0130	1.0186
11	-.15782545		-0.0186	1.0000

From Table 7.1, four factors could be used to cover 96% of the variance. That means that four-factor model could be used to do factor analysis, while keeping most of the information.

By using previous intrinsic factor matrix, the following four-factor model could be constructed. Table 7.2 shows the relationships between new independent factors and original intrinsic factors.

Table 7.2 Rotated Factor Pattern for Intrinsic Factors

	Factor1	Factor2	Factor3	Factor4
Generality	0.48309	0.66639	0.38908	0.17338
Orthoganality	0.11395	0.14528	0.74273	0.11435
Reliability	0.89720	0.29880	0.17027	0.12047
Maintainability	0.74963	0.43166	0.31370	0.25868
Efficiency	0.57386	-0.03712	-0.13451	-0.18188
Simplicity	-0.18260	-0.55663	0.00939	0.65589
Implementability	-0.32839	-0.33896	-0.21451	0.67712
Independence	0.06121	0.78601	-0.03214	-0.21664
Extensibility	0.20115	0.81676	0.30641	-0.16264
Expressiveness	-0.06780	0.13108	-0.01271	0.00867
Influence/Impact	-0.60860	0.04739	0.50057	0.17417

Table 7.3 Factor Analysis for Extrinsic Factor Matrix

	Eigenvalue	Difference	Proportion	Cumulative
1	14.6761315	11.7732953	0.5870	0.5870
2	2.9028361	1.3399175	0.1161	0.7032
3	1.5629186	0.1175127	0.0625	0.7657
4	1.4454059	0.5846837	0.0578	0.8235
5	0.8607222	0.0835462	0.0344	0.8579
6	0.7771760	0.1400264	0.0311	0.8890
7	0.6371496	0.0768753	0.0255	0.9145
8	0.5602743	0.1953426	0.0224	0.9369
9	0.3649316	0.0683321	0.0146	0.9515
10	0.2965995	0.0508914	0.0119	0.9634
11	0.2457081	0.0323457	0.0098	0.9732
12	0.2133624	0.1094646	0.0085	0.9817
13	0.1038978	0.0080606	0.0042	0.9859
14	0.0958372	0.0211755	0.0038	0.9897
15	0.0746617	0.0227643	0.0030	0.9927
16	0.0518974	0.0045546	0.0021	0.9948
17	0.0473428	0.0126464	0.0019	0.9967
18	0.0346964	0.0143009	0.0014	0.9981
19	0.0203954	0.0089244	0.0008	0.9989
20	0.0114710	0.0049902	0.0005	0.9993
21	0.0064809	0.0012417	0.0003	0.9996
22	0.0052391	0.0023913	0.0002	0.9998
23	0.0028478	0.0011691	0.0001	0.9999
24	0.0016787	0.0013407	0.0001	1.0000
25	0.0003380	0.0003380	0.0000	1.0000
26	0.0000000	0.0000000	0.0000	1.0000
27	0.0000000	0.0000000	0.0000	1.0000
28	0.0000000		0.0000	1.0000

Table 7.4 Rotated Factor Pattern for Extrinsic Factors

	Factor1	Factor2	Factor3	Factor4	Factor5	Factor6	Factor7
insintro	-0.16041	-0.04085	0.80553	0.04233	-0.02645	0.14809	0.50985
insuseintro	0.75957	0.29172	0.32479	-0.27850	0.22284	-0.13705	-0.15588
stuuseintro	0.74979	0.23171	0.28506	-0.41273	0.09374	-0.12035	-0.15958
insuse	0.71169	-0.31592	-0.12782	0.26997	0.17357	-0.12884	-0.17960
stuuse	0.90780	-0.15625	-0.07749	0.12515	0.00138	0.04597	0.11277
resprojsur	0.87534	0.08330	-0.02307	-0.06660	-0.14294	-0.13999	0.06847
resprojsubj	0.53265	0.58254	-0.01671	0.05258	0.43498	0.29566	0.05895
cintro	0.16579	0.07377	-0.80300	-0.26373	0.07708	-0.08868	0.41694
Cpri	0.89624	0.15626	0.00588	-0.30354	-0.16720	-0.02907	-0.00278
Devpri	0.90717	0.19859	-0.02433	-0.25508	-0.14503	-0.00652	0.00488
csurpport	0.93734	-0.03438	-0.03061	-0.22961	-0.10977	0.02352	0.04243
devknow	0.88723	-0.22206	0.05365	0.09520	-0.30397	0.08777	-0.03067
comappli	0.88856	0.02094	-0.04748	-0.23799	-0.20923	0.17747	0.00048
Conferences	0.44807	0.72012	-0.06910	0.39840	0.00470	0.06163	0.03921
paperon	0.53373	0.65714	0.03094	0.23015	-0.10628	-0.26950	-0.10528
paperuse	0.57491	0.60515	-0.12026	0.39963	-0.20936	0.15399	0.08022
compilerint	0.81147	-0.40211	-0.02269	0.03117	0.18660	0.22313	-0.09116
debugger	0.81749	-0.47977	-0.03187	0.02496	0.12355	0.22003	0.00551
IDEtool	0.89506	-0.35960	-0.07148	0.04117	-0.05945	0.16147	-0.05297
library	0.85584	0.19923	-0.03516	-0.20527	0.11642	0.32180	-0.04417
Os	0.71927	-0.22971	0.00620	0.44274	0.30975	-0.08673	0.02590
Puse	0.84037	-0.10219	0.05811	-0.08214	0.16875	-0.33998	0.20290
pknow	0.78160	-0.34862	0.07068	0.31976	-0.31624	-0.03279	-0.02154
perwrite	0.83641	-0.31372	0.04769	0.05989	0.10640	-0.27498	0.15101
ugroup	0.90062	0.10474	0.11782	0.17135	0.02410	-0.14135	0.02053

For extrinsic factors, the same method will be used. Table 7.3 shows the factor analysis for extrinsic factors. From this table, following conclusion can be drawn. For the extrinsic factors, seven extrinsic factors will cover 91.45% information. Also, an interesting fact shows that 24 extrinsic factors will cover 100% information, so at least four factors are constant and could be deleted from the model. Table 7.4 shows the seven-factor models.

7.2.2 Canonical Correlation Analysis

There are several measures of correlation to express the relationship between two or more variables. Canonical Correlation is an additional procedure for assessing the relationship between variables. Specifically, this analysis allows us to investigate the relationship between two sets of variables. For example, an educational researcher may want to compute the (simultaneous) relationship between three measures of scholastic ability with five measures of success in school. If the square root of the eigenvalues is taken, then the resulting numbers can be interpreted as correlation coefficients. Because the correlations pertain to the canonical varieties, they are called Canonical Correlations. Like the eigenvalues, the correlations between successively extracted canonical variants are smaller and smaller. Therefore, as an overall index of the canonical correlation between two sets of variables, it is customary to report the largest correlation, that is, the one for the first root. However, the other canonical variants can also be correlated in a meaningful and interpretable manner.

In this project, canonical correlation is used to analyze the relationship among all factors. Two kinds of canonical analysis have been done: one with only the factors in intrinsic group, and the other with both intrinsic and extrinsic factors.

The first is done to seek the interest relationships between intrinsic features of language and performance of them. Most result showed a relationship, which counts for part of the feature. Different intrinsic factors of a programming language do have different impact on the overall performance by using this model. Let's check table 7-5 for the question: "How many developers consider this language as primary language?"

Table 7.5 Sample Correlation Results for Intrinsic Factors Only

	How many developers consider this language as primary language?
Generality	0.6913
Orthoganality	0.0199
Reliability	0.3199
Maintainability	0.0470
Efficiency	0.0703
Simplicity	-0.4703
Implementability	-0.3390
Independence	0.8876
Extensibility	0.7625
Expressiveness	0.3024
Influence/Impact	0.0552
Year	-0.5055

Table 7.5 shows that machine independence, extensibility and generality have more impact to this extrinsic factor than other intrinsic factors. Please notice that year will also have relatively big impact to the trends. In the long term, older programming language will lose its popularity during the time.

The second model is done to show the correlations between all variables, including both intrinsic and extrinsic factors. Most of the time, the relationships in the first part now are not in the first rank. Some relationships are very interesting, like those relations with variables from technology groups, some are just shows the highly related facts between some variables. However, these are still important information in the prediction model construction.

Let's analyze the result of canonical correlation analysis by using all factors for the extrinsic factor: "How many developers consider this language as primary language?" The correlation results shows that intrinsic factors don't have much impact on this extrinsic factor. Instead, those extrinsic factors like: "How many companies use this language as primary language", "How many compiler available for this programming language", and "How many people consider this language as their primary language", are highly related with this extrinsic factor. Table 7.6 shows some of the correlation results.

Table 7.6 Sample Correlation Results for All Factors

How many developers consider this language as primary language?	
How many companies use this language as primary language?	0.9922
How many developers know this language?	0.7581
How many people consider this language as their primary language?	0.9358
How many compilers available for this programming language?	0.8989
How many students consider this language as their primary language?	0.8697
……	……

7.2.3 Statistics Conclusion

First, for intrinsic factors, the factor analysis showed that only four intrinsic variables are enough to contain more than 95% of the language internal information. So, it shows that the 11 latent intrinsic factors are highly correlated and they are not independent from each other. To construct useful regression model for the historical trends, the independent factors, instead of original factors, will be used. From the factor analysis, it shows that intrinsic variables do represent important features of the language.

Second, for extrinsic factors, the factor analysis showed that only seven extrinsic variables are enough to contain more than 95% information of all extrinsic factors. That means most of the 30 extrinsic factors are also related to each other. The high correlation between all extrinsic variables represent that there are some highly-correlated variables in the extrinsic group. It makes sense. For example, the more institutions use a programming language as introductory teaching language, the more students will know this programming language; the more companies use a programming language to develop their software, the more developers will consider this programming language as their primary language.

The canonical correlation analysis result shows that which factors are mostly related and how much are they related. Thus manifest the relationship between intrinsic factors and extrinsic factors quantitatively. It is also a good startup to construct regression model, because the newly constructed independent factors, instead of the original factors, will be used to construct the regression model.

7.3 Model Construction

After factor analysis has been done, the independent intrinsic and extrinsic factors have been constructed. By doing canonical correlation analysis, two correlation models for intrinsic factors only and for all factors have been made to show the correlation among those factors. Section 7-3 will discuss how to construct regression models by using these independent intrinsic and extrinsic factors.

7.3.1 Multivariate Multiple Regression Model

Regression analyses are a set of statistical techniques that allow one to assess the relationship between one dependent variable (DV) and several independent variables (IVs). Multiple regression is an extension of bivariate regression in which several independent variables are combined to predict the dependent variable. Regression may be assessed in a variety of manners, such as:

- Partial regression and correlation: Isolates the specific effect of a particular independent variable controlling for the effects of other independent variables. To find out the relationship between pairs of variables while recognizing the relationship with other variables.
- Multiple regression and correlation: Combined effect of all the variables acting on the dependent variable; for a net, combined effect. The resulting R2 value provides an indication of the goodness of fit of the model.

The multivariate regression equation is of the form:

$$Y = A + B_1X_1 + B_2X_2 + \ldots + B_kX_k + E$$

where:

Y = the predicted value on the DV,

A = the Y intercept, the value of Y when all Xs are zero,

X = the various IVs,

B = the various coefficients assigned to the IVs during the regression,

E = an error term.

Accordingly, a different Y value is derived for each different case of independent variable. The goal of the regression is then to derive the B values, the regression coefficients, or beta coefficients. The beta coefficients allow the computation of reasonable Y values with the regression equation, and provide that calculated values are close to actual measured values.

Computation of the regression coefficients provides two major results:

- Minimization of deviations (residuals) between predicted and obtained Y values for the data set,
- Optimization of the correlation between predicted and obtained Y values for the data set.

As a result, the correlation between the obtained and predicted values for Y relates the strength of the relationship between the dependent variable and independent variables. Although regression analysis reveals relationships between variables, this does not imply that the relationships are causal. Demonstration of causality is not a statistical problem, but an experimental and logical problem. Multiple regression is a good choice for us to analyze the programming trends.

7.3.2 Regression Model for Historical Trends

In this project, multivariate multiple regression model is used to analyze the data. Please check Figure 7-2.

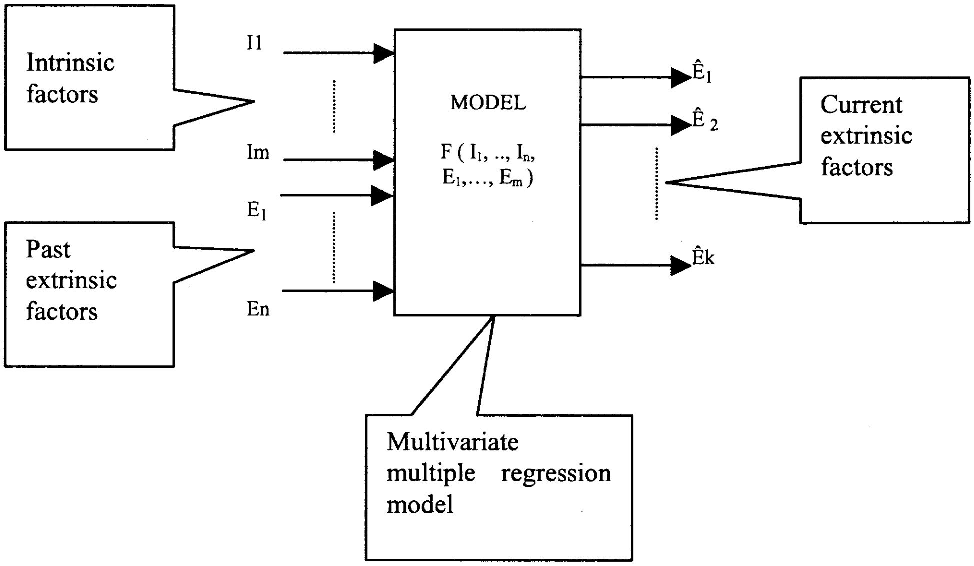

Intrinsic factors
I1
Im
E1
En
Past extrinsic factors
MODEL
F (I1, .., In, E1,..., Em)
Ê1
Ê 2
Êk
Current extrinsic factors
Multivariate multiple regression model

Figure 7.2 Regression model for programming language trends.

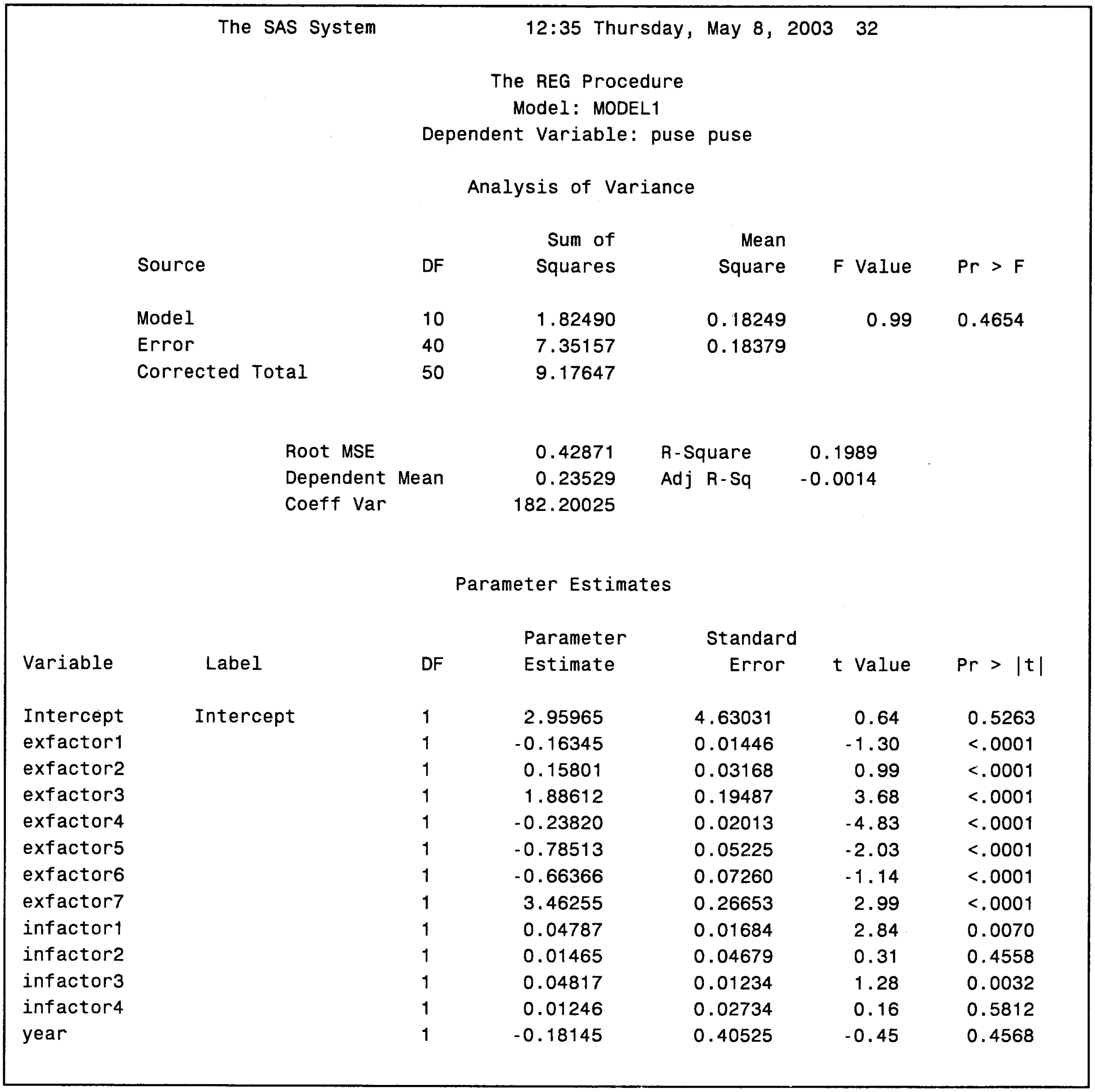
In this model, all of the intrinsic factors will be considered as input factors. Extrinsic factors, which will changed by time, will be consider as both input and output factors. Normally, the earlier history data will be considered as input factors and the later data will be considered as output factors.

Input data: Intrinsic factors and Extrinsic factors

Output data: Extrinsic factors

The general purpose of multivariate multiple regression is to learn more about the relationship between several independent or predictor variables and a dependent or criterion variable. Multivariate multiple regression can easily be extended to deal with situations where the response consists of $p > 1$ different variables. The input matrix will be constructed by factors got from factor analysis, this analysis is necessary to make independent factors so the regression model can be made and interpreted.

Multivariate multiple regression model for programming trends consists 30 parts, one for each extrinsic variables. Due to the number of factors used in the model, there will be a balance between model reliability and the information completion. The more factors you used, the more information will be included, but regression model will be less reliable. The fewer factors you used, the less information will be included, but the regression model will be more reliable.



```
                The SAS System          12:35 Thursday, May 8, 2003  32

                                   The REG Procedure
                                    Model: MODEL1
                             Dependent Variable: puse puse

                                 Analysis of Variance

                                         Sum of           Mean
        Source                  DF      Squares         Square    F Value    Pr > F

        Model                   10      1.82490        0.18249       0.99    0.4654
        Error                   40      7.35157        0.18379
        Corrected Total         50      9.17647


                  Root MSE              0.42871    R-Square     0.1989
                  Dependent Mean        0.23529    Adj R-Sq    -0.0014
                  Coeff Var           182.20025


                                 Parameter Estimates

                                        Parameter       Standard
   Variable        Label           DF    Estimate          Error    t Value    Pr > |t|

   Intercept      Intercept         1     2.95965        4.63031       0.64      0.5263
   exfactor1                        1    -0.16345        0.01446      -1.30      <.0001
   exfactor2                        1     0.15801        0.03168       0.99      <.0001
   exfactor3                        1     1.88612        0.19487       3.68      <.0001
   exfactor4                        1    -0.23820        0.02013      -4.83      <.0001
   exfactor5                        1    -0.78513        0.05225      -2.03      <.0001
   exfactor6                        1    -0.66366        0.07260      -1.14      <.0001
   exfactor7                        1     3.46255        0.26653       2.99      <.0001
   infactor1                        1     0.04787        0.01684       2.84      0.0070
   infactor2                        1     0.01465        0.04679       0.31      0.4558
   infactor3                        1     0.04817        0.01234       1.28      0.0032
   infactor4                        1     0.01246        0.02734       0.16      0.5812
   year                             1    -0.18145        0.40525      -0.45      0.4568
```

Figure 7.3 Sample SAS regression model report for one extrinsic factor.

Please check Figure 7.3. This figure is a sample SAS report for the multivariate multiple regression model, which uses seven independent extrinsic factors, four independent intrinsic factors, and year as input independent variables. This report will show the regression model for one extrinsic factor: "How many people consider this language as primary language." The parameter will show the impact of each input independent factor to the output extrinsic factor. The other regression reports can be found in the website of this project. By using all of the parameters, the regression models are constructed for historical programming language trends.

In a word, this multivariate multiple regression models are used to describe the historical trends of every programming languages. This statistics models are very helpful to see the relationships among all factors and how they affect the programming language trends.

CHAPTER 8

TOWARDS A PREDICTIVE MODEL

8.1 Model Derivation

In order to predict the future trends of programming languages, the original multivariate multiple regression models should be revised. The model derivations are divided into three parts: data reorganization, variable choosing & primary model calculation, and variables reselection & final model calculation.

The first step is data reorganization. In this step, the factors will be redefined. For example, the variable PUSE means "how many people know this language at a specific time?" And this variable used to have 51 observations for 17 programming languages in 3 periods (1993, 1998, 2003). Now, this factor will be divided into PUSE93, PUSE98 and PUSE03, each has 17 observations for each period (1993, 1998 and 2003). In this way, only the extrinsic factors need be reorganized. Intrinsic factors do not need reorganization because they will not change with time. In this way, the whole structure of the data is changed like the following. There are only 17 observations/languages, but much more variables, because the number of extrinsic variables has been tripled. This will cause special model calculation methods in the future.

For variable choosing and model primary calculation, the following steps will be done. Refer to the correlation coefficients got by canonical analysis, two to three variables will be chosen from each group, such as grassroots support group, the standard is to choose the most highly related ones. The choosing will continue until there are more than 16 variables in the PROC REG in SAS. Then the first calculation will begin by running the PROC. SAS will automatically check the variables, decide which to keep and which to delete. The Result will be a list that shows that some variables are dependent on others and should be erased from the model.

The last step is variables reselection and the final model calculation. All dependent variables should be deleted from the original model. It will be only 16 variables left on the right side of the equation mark. Now run the PROC again and get the final model. The coefficients for each variable are now fixed and can be recorded.

By doing so, derivative regression models are constructed like the following:

$$E_{2003} = A * I + B * E_{1998} + C * E_{1993} + D$$

Where:

E_{2003}: Value of extrinsic factors in 2003

I: Value of intrinsic factors

A: Parameter matrix for intrinsic factors

E_{1998}: Value of extrinsic factors in 1998

B: Parameter matrix for extrinsic factors in 1998

E_{1993}: Value of extrinsic factors in 1993

C: Parameter matrix for extrinsic factors in 1993

D: Constant value

SAS is used to calculate the parameter matrix. Please notice that there exists more than one parameter matrix for this model because the number of parameter is greater than the number of observation. Although multiple parameter matrices exist in this derivative model, they are still useful and can be used to describe the historical trends of programming languages.

8.2 Predictive Model

From previous section, the derivative prediction models have been constructed for each extrinsic factor in 2003. Based on the assumption that the whole language trends from 1998 to 2008 should be similar like those from 1993 to 2003, the following derivative models will be used to predict the value of each extrinsic factor in 2008 by submitting the value in 98 to the 93 position and 03 to the 98 position in the model.

$$E_{2008} = A * I + B * E_{2003} + C * E_{1998} + D$$

where:

E_{2008}: Value of extrinsic factors in 2008

I: Value of intrinsic factors

A: Parameter matrix for intrinsic factors

E_{2003}: Value of extrinsic factors in 2003

B: Parameter matrix for extrinsic factors in 2003

E_{1998}: Value of extrinsic factors in 1998

C: Parameter matrix for extrinsic factors in 1998

D: Constant value

Some of the predictions are showed in the rest of this chapter. Let's check "How many people will consider this language as their primary programming Language in 2008?" The following is the predictive results:

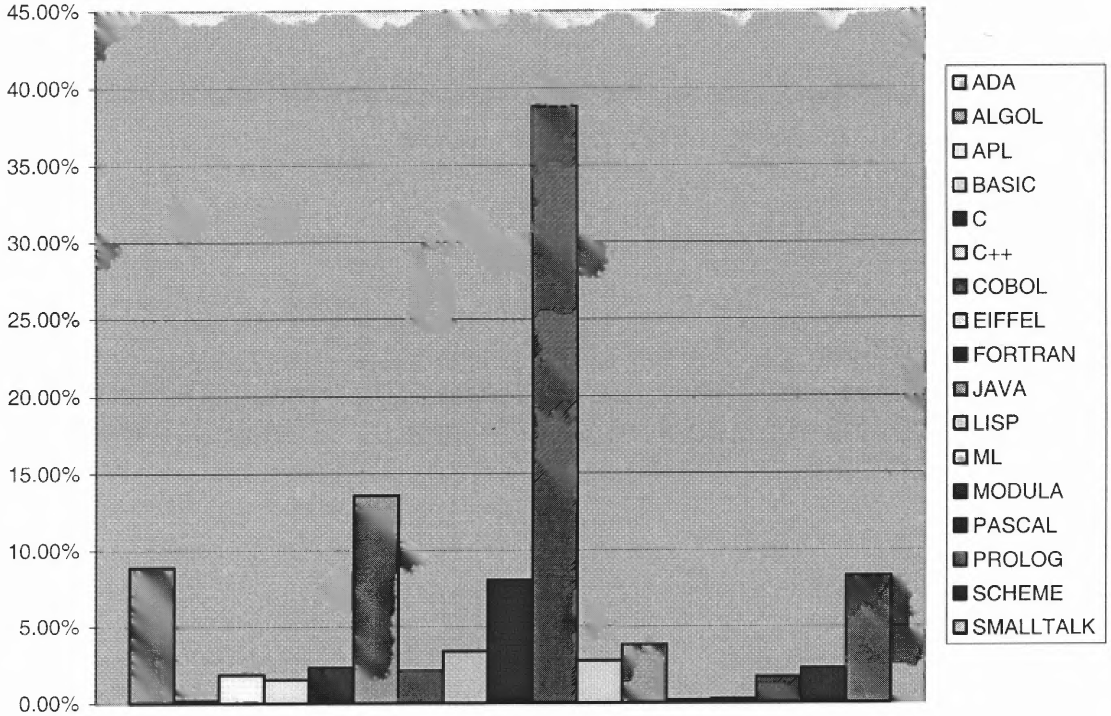
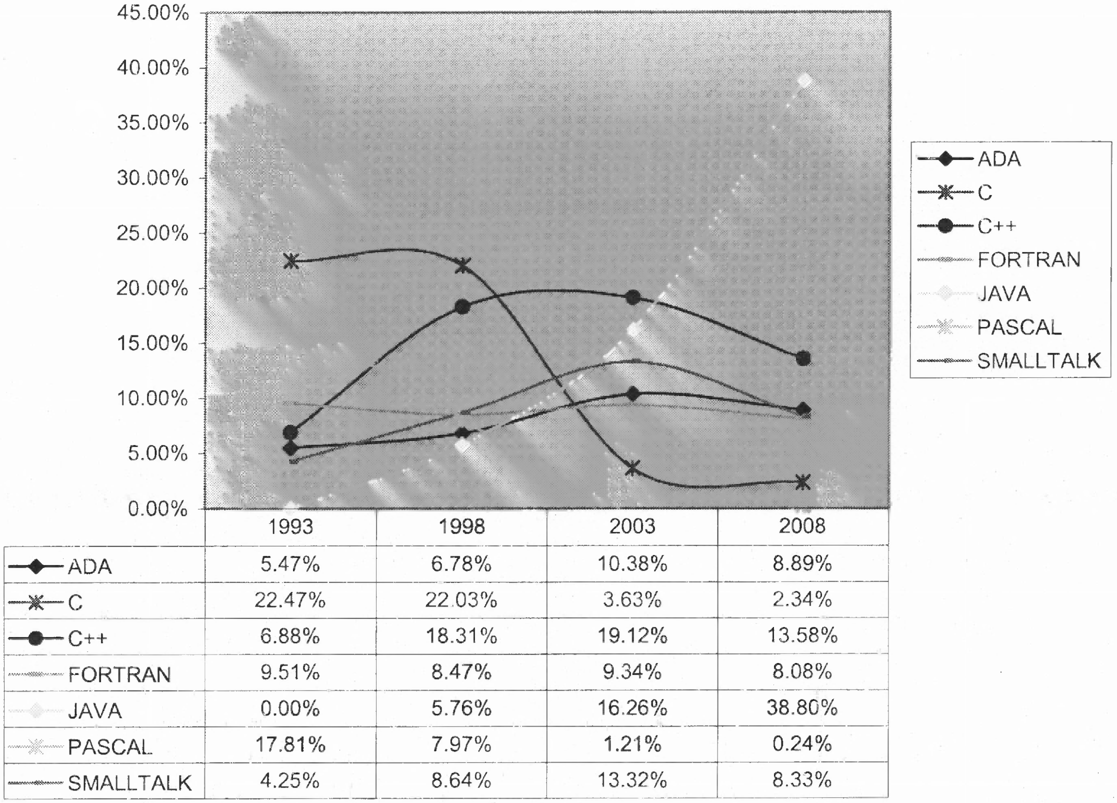


Figure 8.1 How many people consider this language as primary language in 2008.

From above graphs, the five most popular languages in 2008 will be: JAVA (38.8%), C++ (13.58%), ADA (8.89%), SMALLTALK (8.33%), and FORTRAN

(8.08%). Figure 8.2 shows the trends of most popular programming languages from 1993 to 2008.



	1993	1998	2003	2008
◆ ADA	5.47%	6.78%	10.38%	8.89%
✱ C	22.47%	22.03%	3.63%	2.34%
● C++	6.88%	18.31%	19.12%	13.58%
FORTRAN	9.51%	8.47%	9.34%	8.08%
JAVA	0.00%	5.76%	16.26%	38.80%
PASCAL	17.81%	7.97%	1.21%	0.24%
SMALLTALK	4.25%	8.64%	13.32%	8.33%

Figure 8.2 Trends of most popular programming languages from 1993 to 2008.

Figure 8.2 shows interesting trends for programming language. It seems like from 2003 to 2008, JAVA will be the only language that is still in increasing period. All the other languages will decline and begin to enter a stable period where the percentage won't change too much.

Please notice that this prediction is based on historical trends. That means if future trends remain the same as current trends, JAVA will still keep growing. But it's maybe not true because nobody can guarantee that the future trends of next five years will be the same like last five years, and the newest language (like C#) is not considered.

Figure 8.3 shows another interesting question for grassroots support: "How many people know this Language in 2008?"

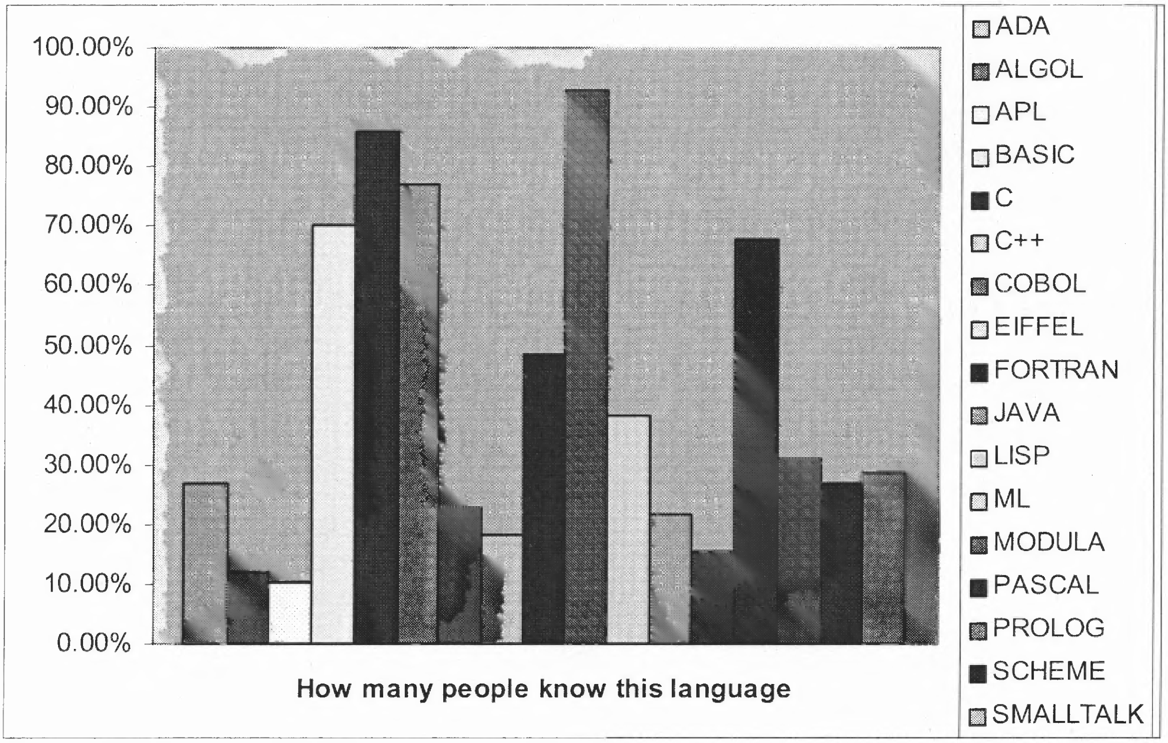
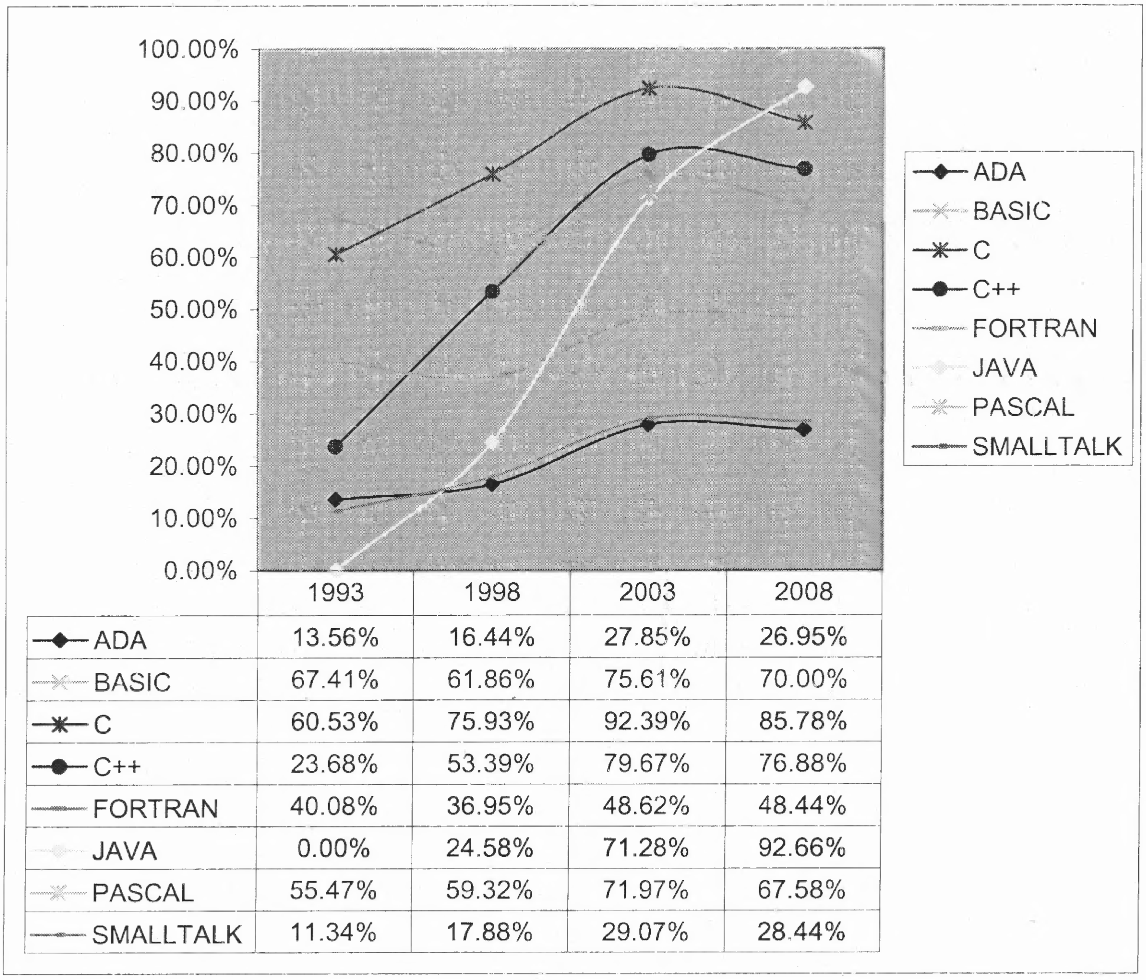


Figure 8.3 How many people will know this language in 2008.

From above graphs, the top five most-people-known languages in 2008 will be: JAVA (92.66%), C (85.78%), C++ (76.88%), BASIC (70.02%), PASCAL (67.58%), and FORTRAN (8.08%).

Figure 8.3 shows JAVA will bypass C as the most-people-known language in 2008. Figure 8.4 shows the trends of most-people-known programming languages from 1993 to 2008.



	1993	1998	2003	2008
ADA	13.56%	16.44%	27.85%	26.95%
BASIC	67.41%	61.86%	75.61%	70.00%
C	60.53%	75.93%	92.39%	85.78%
C++	23.68%	53.39%	79.67%	76.88%
FORTRAN	40.08%	36.95%	48.62%	48.44%
JAVA	0.00%	24.58%	71.28%	92.66%
PASCAL	55.47%	59.32%	71.97%	67.58%
SMALLTALK	11.34%	17.88%	29.07%	28.44%

Figure 8.4 Trends of most-people-known languages from 1993 to 2008.

Figure 8.4 also shows interesting trends for programming language. It seems like from 2003 to 2008, JAVA still growing very fast while the other languages won't change much. Although ADA ranks No. 3 as primary language, but not much people know it.

The best explanation is that certain group of people likes ADA very much while the other people even won't bother to learn it.

A very important fact is that the parameter matrices are not unique. All of these parameter matrices could be used to describe past and current trends of programming languages, because that is how they are constructed. But by replacing the data of 1993 by those of 1998 and replacing the data of 1998 by those of 2003, the results of 2008 are not the same by using different parameter matrices. That means each predictive derivation model will generate different prediction results. Although the predictions are not unique, these derivative models are still very helpful for researchers to understand the trends. After collecting more data in the future, these derivative models can be refined.

CHAPTER 9

MODEL VALIDATION & IMPROVEMENT

9.1 Model Validation

In this empirical study, programming language trends were considered, their evolution over time was observed, the evolution by means of time series was recorded, and the general statistics models for how these trends evolve have been constructed.

After the statistics models for programming language trends have been constructed, a number of methods need to be introduced to assess the reliability of these models. Assessing the quality of a model is called model validation. Model validation is something that needs to be done both by producers and users of models. A model is just a human being's hypothesis of a simplified representation of the real world, so it is always a good practice to do validation to check the reliability of a model.

In this project, the following methods will be used to validate the statistics models:

- Check the difference between the actual values and the predictive values from the statistical models.
- Use historical data of the other programming languages that are not in our language list to validate and correct the model.
- Revise these models based on the newest evolution of programming languages.

Table 9.1 Difference between Actual Value and Predictive Value in 2003

	Actual Value	Predictive Value
ADA	161	215
ALGOL	12	16
APL	8	19
BASIC	1498	1244
C	2864	2082
C++	2658	2016
COBOL	324	267
EIFFEL	183	222
FORTRAN	406	394
JAVA	2465	1954
LISP	238	240
ML	32	74
MODULA	23	51
PASCAL	1683	1203
PROLOG	206	229
SCHEME	38	75
SMALLTALK	312	263

F-Statistic, which is a standard statistical method to check if there are significant differences between 2 groups, is used to validate the prediction.

F=190800.24/812505.4=0.235

(The calculation process is like below:

A1=13111 A2=10564 T=A1+A2=23675 S1=1025.83 S2=756.753

Mean1=771.235 Mean2=621.412

[Y]=42676433 [A]=(171898321+111598096)/17= 283496417/17=16676259.8

[T]=560505625/2*17=16485459.56

SSt=[Y]-[T]=26190973.44 SSs/a=[Y]-[A]=26000173.2

SSa=[A]-[T]=190800.24)

MSa=SSa/dfa=190800.24 MSs/a=SSs/a / dfs/a= 26000173.2/32=812505.4

F=190800.24/812505.4=0.235)

In the F-table, a=0.05, F>4.49 to reject Hypothesis, so F value is much less. The hypothesis is validated, since there is no significant difference between these 2 groups. The prediction is very well when tested with actual value.

Table 9.1 shows the difference between the actual values and the predictive values for the extrinsic factor: "How many people know this programming language in 2003?" It shows that the predictive values match actual values very well and this statistical model is valid to describe the historical and current trends of programming languages.

9.2 Model Improvement

9.2.1 Weakness

There no perfect statistics models exist. A famous statistic statement is: "All models are wrong, but they are useful." Instead of perfect models, reasonable models are maintained to describe the historical trends and current evolution of programming languages. Somehow, these models can also be used as good references to predict the future trends of programming languages. This multiple regression model for programming language trends has the following weaknesses.

The first weakness of the regression model is that the number of the variables is larger than the number of observations. It makes the regression models to be not unique. To avoid that problem, two ways will be used to refine the models. Most correlated variables are always manually selected into the model first. SAS will also automatically delete the dependent variables until 17 variables (equal to the number of the observations) can be decided. In the future, it is hoped that more language will be included into the research so the number of observation can increase and make the model sounder.

The second weakness is that the data may not in proper format or not complete. In the data survey process, some problems are difficult to solve. And bias may be caused. For example, not every company responds to the survey, so the information is incomplete. If the silent companies are tending more to use one kind of specific language, a bias will be caused by the available data. Also, it is hard to get cooperation from government, because they are not willing to participate the survey.

Also, some historical data are hard to find and the expression maybe not good. For example, as the variable PUSE is considered, it will vary a lot in different periods. The 300 users in 1980 may consist 90% of all programmers, so C++ should be considered to be prevailing at that time. However, it will be considered as much less important comparing to the 3000 users for JAVA in 2003 just because of the small number. But in the year of 2003, 3000 users may just consist a small proportion of the programmers. Due to the dramatic development of computer science and technology, the number may not be a good measure. But, if percentage is used instead of number, information of number growth will be lost. So, both number and percentage should be considered when analyzing the data and constructing the statistics models.

The features of the programming languages may prove that multiple multivariate regression models are not the best method for analysis. The feature of a new programming language may appear to be like the description below:

"A programming language will first expand after it's created, increasing even in exponent way. Then, it goes to the summit in a few years. As time is going on and newer language coming out, it begins a decrease period. Then after a change period, it keeps somehow constant. There will not have much vibration for the rest of its life. The lifecycle of a programming language likes a bell curve."

This description is reasonable based on the common sense of a programming language. However, it is far from what we get in this multiple multivariate models. So that multiple multivariate regression may not be very appropriate here, or can be considered just as an approximation. However, we need more data to track the whole process instead of 3 periods. If we have more data, we will use time series method to reanalyze it.

9.2.2 Possible Improvement

To investigate the future data, more observations are needed. And based on more data, TIME SERIES method can be used to construct better statistics models. There are two main goals of time series analysis: identifying the nature of the phenomenon represented by the sequence of observations, and predicting future values of the time series variable. Both of these goals require that the pattern of observed time series data is identified and more or less formally described.

Time series data often arise when monitoring industrial processes or tracking corporate business metrics. Time series analysis accounts for the fact that data points taken over time may have an internal structure, such as autocorrelation, trend or seasonal variation. The below introduction of Time Series: [66]

Time series model is an ordered sequence of values of a variable at equally spaced time intervals. The usage of time series models is twofold:

- Obtain an understanding of the underlying forces and structure that produced the observed data
- Fit a model and proceed to forecasting, monitoring or even feedback and feedforward control.

The fitting of time series models can be an ambitious undertaking. There are many methods of model, such as Box-Jenkins ARIMA models, Box-Jenkins Multivariate Models, Holt-Winters Exponential Smoothing (single, double, triple), and Box-Jenkins ARIMA models.

The term "univariate time series" refers to a time series that consists of single (scalar) observations recorded sequentially over equal time increments. Some examples are monthly CO_2 concentrations and southern oscillations to predict el nino effects.

Although a univariate time series data set is usually given as a single column of numbers, time is in fact an implicit variable in the time series. If the data are equi-spaced, the time variable, or index, does not need to be explicitly given. The time variable may sometimes be explicitly used for plotting the series. However, it is not used in the time series model itself.

Box-Jenkins Multivariate Models

The multivariate form of the Box-Jenkins univariate models is sometimes called the ARMAV model, for Auto Regressive Moving Average Vector or simply vector ARMA process.

The ARMAV model for a stationary multivariate time series, with a zero mean vector, represented by

$$x_t = (x_{1t}, x_{2t}, ..., x_{nt})^T \qquad -\infty < t < \infty$$

is of the form

$$\begin{aligned}\mathrm{x}_t &= \phi_1 x_{t-1} + \phi_2 x_{t-2} + \ldots + \phi_p x_{t-p} + a_t \\ &- \theta_1 a_{t-1} - \theta_2 a_{t-2} - \ldots - \theta_q a_{t-q}\end{aligned}$$

where

$\boldsymbol{x_t}$ and $\boldsymbol{a_t}$ are n x 1 column vectors with $\boldsymbol{a_t}$ representing multivariate white noise

$$\phi_k = \{\phi_{k.jj}\}, \qquad k = 1, 2, \ldots, p$$

$$\theta_k = \{\theta_{k.jj}\}, \qquad k = 1, 2, \ldots, q$$

are n x n matrices for autoregressive and moving average parameters

$$\mathrm{E}[\boldsymbol{a_t}] = \mathbf{0}$$

$$E(a_t a'_{t-k}) = 0 \qquad k \neq 0$$

$$E(a_t a'_{t-k}) = \Sigma_a \qquad k = 0$$

where Σ_a is the dispersion or covariance matrix of a_t

As an example, for a bivariate series with $n = 2$, $p = 2$, and $q = 1$, the ARMAV(2,1) model is:

$$\begin{pmatrix} x_{1t} \\ x_{2t} \end{pmatrix} = \begin{pmatrix} \phi_{1.11} & \phi_{1.12} \\ \phi_{1.21} & \phi_{1.22} \end{pmatrix} \begin{pmatrix} x_{1t-1} \\ x_{2t-1} \end{pmatrix} +$$

$$\begin{pmatrix} \phi_{2.11} & \phi_{2.12} \\ \phi_{2.21} & \phi_{2.22} \end{pmatrix} \begin{pmatrix} x_{1t-2} \\ x_{2t-2} \end{pmatrix}$$

$$+ \begin{pmatrix} a_{1t} \\ a_{2t} \end{pmatrix} - \begin{pmatrix} \phi_{1.11} & \phi_{1.12} \\ \phi_{1.21} & \phi_{1.22} \end{pmatrix} \begin{pmatrix} a_{1t-1} \\ a_{2t-1} \end{pmatrix}$$

with

$$a_t = \begin{pmatrix} a_{1t} \\ a_{2t} \end{pmatrix}$$

The estimation of the matrix parameters and covariance matrix is complicated and very difficult without computer software. The estimation of the Moving Average matrices is especially an ordeal. If we opt to ignore the MA components we are left with the ARV model given by:

$$x_t = \phi_1 x_{t-1} + \phi_2 x_{t-2} + \ldots + \phi_p x_{t-p} + a_t$$

where

x_t is a vector of observations, $x_{1t}, x_{2t}, \ldots, x_{nt}$ at time t

a_t is a vector of white noise, $a_{1t}, a_{2t}, \ldots, a_{nt}$ at time t

$\phi_k = \{\phi_{k.jj}\}, \quad k = 1, 2, \ldots, p$

is a n x n matrix of autoregressive parameters

$\mathrm{E}[a_t] = \mathbf{0}$

$E(a_t a'_{t-k}) = 0 \quad k \neq 0$

$E(a_t a'_{t-k}) = \Sigma_a \quad k = 0$

where $\Sigma_a = \mathrm{E}[a_t, a_{t-k}]$ is the dispersion or covariance matrix

A model with p autoregressive matrix parameters is an ARV(p) model or a vector AR model. The parameter matrices may be estimated by multivariate least squares, but there are other methods such as maximum likelihood estimation.

There are a few interesting properties associated with the phi or AR parameter matrices. Consider the following example for a bivariate series with n =2, p = 2, and q = 0. The ARMAV(2,0) model is:

$$\begin{pmatrix} x_t \\ y_t \end{pmatrix} = \begin{pmatrix} \phi_{1.11} & \phi_{1.12} \\ \phi_{1.21} & \phi_{1.22} \end{pmatrix} \begin{pmatrix} x_{t-1} \\ y_{t-1} \end{pmatrix} + \begin{pmatrix} \phi_{2.11} & \phi_{2.12} \\ \phi_{2.21} & \phi_{2.22} \end{pmatrix} \begin{pmatrix} x_{t-2} \\ y_{t-2} \end{pmatrix} + \begin{pmatrix} a_{1t} \\ a_{2t} \end{pmatrix}$$

Without loss of generality, assume that the *X* series is input and the *Y* series are output and that the mean vector = (0,0). Therefore, transform the observation by subtracting their respective averages.

The diagonal terms of each Phi matrix are the scalar estimates for each series, in this case:

$\phi_{1.11}$, $\phi_{2.11}$ for the input series *X*,

$\phi_{1.22}$, $\phi_{2.22}$ for the output series *Y*.

The lower off-diagonal elements represent the influence of the input on the output. This is called the transfer mechanism or transfer-function model as discussed by Box and Jenkins in Chapter 11. The ϕterms here correspond to their δterms.

The upper off-diagonal terms represent the influence of the output on the input. This is called "feedback". The presence of feedback can also be seen as a high value for a coefficient in the correlation matrix of the residuals. A "true" transfer model exists when there is no feedback. This can be seen by expressing the matrix form into scalar form:

$$x_t = \phi_{1.11}x_{t-1} + \phi_{2.11}x_{t-2} + \phi_{1.12}y_{t-1} + \phi_{2.12}y_{t-2} + a_{1t}$$

$$y_t = \phi_{1.22}u_{t-1} + \phi_{2.22}y_{t-2} + \phi_{1.21}x_{t-1} + \phi_{2.21}x_{t-2} + a_{2t}$$

Finally, delay or "dead' time can be measured by studying the lower off-diagonal elements again. If, for example, $\phi_{1.21}$ is non-significant, the delay is 1 time period.

Holt-Winters Exponential Smoothing (single, double, triple)

This is a very popular scheme to produce a smoothed Time Series. Whereas in Single Moving Averages the past observations are weighted equally, Exponential Smoothing assigns exponentially decreasing weights as the observation get older. In other words, recent observations are given relatively more weight in forecasting than the older observations.

In the case of moving averages, the weights assigned to the observations are the same and are equal to $1/N$. In exponential smoothing, however, there are one or more smoothing parameters to be determined (or estimated) and these choices determine the weights assigned to the observations.

By previous analysis, Time Series method can focus on the internal trend of the data, which is just our interest – to find the internal trend of the development of a programming language. However, Time Series requires much more data then we now have. It needs a long time following and correct recording. We will choose time series method when the pre-requirement is met.

CHAPTER 10

CONCLUSION AND FUTURE WORK

10.1 Summary

In this dissertation, a tentative effort has been discussed to analyze programming language trends and how they evolve. The topics studied here include: what are the factors that could affect the programming language trends; how to quantify these factors; how to collect data for these factors; how to construct statistics models to describe the evolution of programming languages; how to use these models to predict the future trends; and how to validate and improve the statistics models.

As part of software engineering technology trends, this dissertation is concentrated on a family of the trends: programming languages. First, the author discussed what could be the possible factors that can affect the trends of programming languages. The evolution of programming languages is affected by a dizzying array of factors, which are themselves driven by a wide range of sources, such as market forces, corporations, government agencies, standards bodies, universities, etc. In author's point of view, both intrinsic factors and extrinsic factors would have impact on the trends of programming languages. After discussing the definition of intrinsic factors and extrinsic factors, a group of factors that could be used to watch programming languages trends are identified.

In order to use empirical method to analyze the trends, a way must be found to quantify intrinsic factors and extrinsic factors of programming languages. To quantify intrinsic factors, all features of a programming language should be reviewed to check if they match these factors, and scores will be assign for them. Extrinsic factors are not the same as intrinsic factors. Basically, they are questions for different fields. Extrinsic factors are questions that ask for the numbers, so the answers will be used as the value of this extrinsic factor.

By using this quantifying method, a couple of surveys have been done to collect necessary data for both intrinsic factors and extrinsic factors. A set of programming languages has been selected, and intrinsic factors are evaluated based on the first version of each programming language. For extrinsic factors, surveys have been done for each field of them in 1993, 1998 and 2003. The value of intrinsic factor will not change during the time, while the value of extrinsic factor does change in different period. All data are stored in a data warehouse. Please check the complete survey results at http://swlab.njit.edu/techwatch.

Based on this data warehouse, statistics methods are used to analyze these data. Several statistics models are constructed to describe the relationships among these factors and the historical trends of each programming language. Canonical correlation is used to do the factor analysis. Correlation among these factors has been analyzed and new independent factors are constructed by using factor analysis. Multivariate multiple regression method has been used to construct the statistics models for programming language trends.

After statistics models are constructed to describe the historical programming language trends, they will be extended to do tentative prediction for future trends. The prediction model can be validated by future data.

10.2 Evaluation

In this empirical study for programming language trends, the author merely attempt to capture observed behaviors by empirical laws. After having collected enough data and constructed statistics models, the trends of programming languages could be understood better. By factor analysis, each factor gets a parameter. The guess is that the factors with larger parameter will have bigger impact to evolution of programming languages. By this means, the following conclusion can be drawn:

- From the statistics models, generally, the parameters of extrinsic factors are greater than the parameters of intrinsic factors. So, extrinsic factors have bigger impact than intrinsic factors.
- Extrinsic factors can be used to check if a programming language succeeds or fails. They are also very important factors to predict the future evolution of a programming language. In author's point of view, if a programming language can earn support from the majority of one field, it can be called a successful language, such as ADA, SMALLTALK. If a programming language can earn support from the majority of grassroots and every field, it can be considered as very successful programming language, such as C++, JAVA.
- Although intrinsic factors have less impact than extrinsic factors, they do impact the trends of programming languages, especially machine independence, extensibility, and generality.

Another very important factor is the time. The survey results show that the feature of a new programming language may appear to be like the description below: When a programming language is introduced, there are some enthusiasts who are willing to learn it. The language could expand at first, increases even in exponent way. After a while, there will be more people who would like to use this programming language. Then, as newer language coming out, the older language will pass its summit and begin to decrease. After a changing period, it keeps somewhat constant because there are certain group of people who would like to stick to this language. The language will exist without much vibration in the rest of its life. The life cycle of a programming language are very similar with Geoffrey A. Moore's technology adoption life cycle (TALC [4]). Figure 10.1 shows the general lifecycle of a programming language.

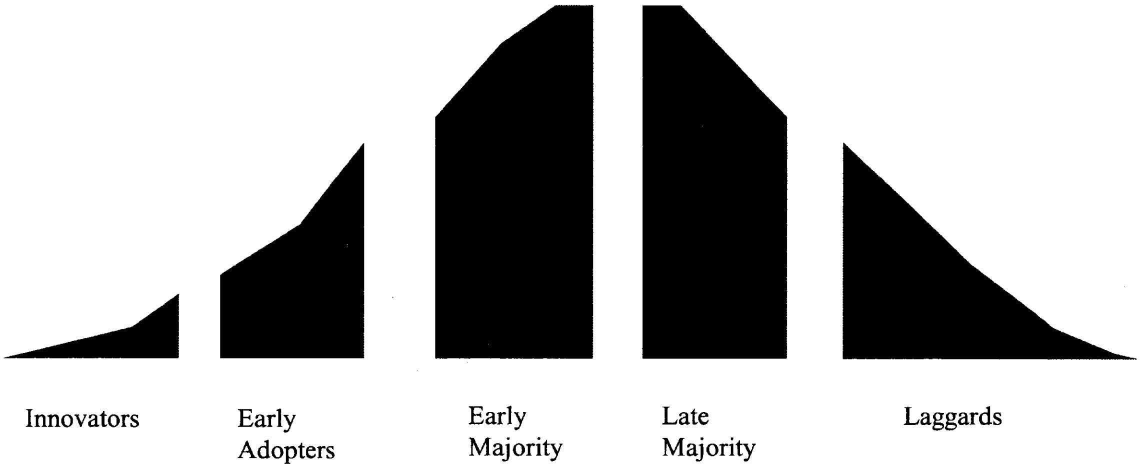


Figure 10.1 General lifecycle of a programming language.

The bell curve in Figure 10.1 is very useful as the general analytical model for the trends of programming languages. The empirical results could be used to explain why a successful programming language could earn the support from majority programmer and why the other ones failed although a lot of innovators support them.

10.3 Future Work

A lot of data and interesting survey results have been collected in this empirical research for programming language trends, but they are still not enough. If more data could be collected in the future, they can be used to improve current statistics models. Instead of using correlation and regression models, more advanced statistics methods, such as time series method, can be used to improve current models in the future.

Empirical study for programming languages is just a tentative beginning of the whole project of software engineering trends. After using empirical method, analytical method will be used for programming language trends. Future work will not only attempt to capture observed behaviors by empirical laws, but also attempts to understand the phenomena that underlie observed behavior and build models that capture these phenomena.

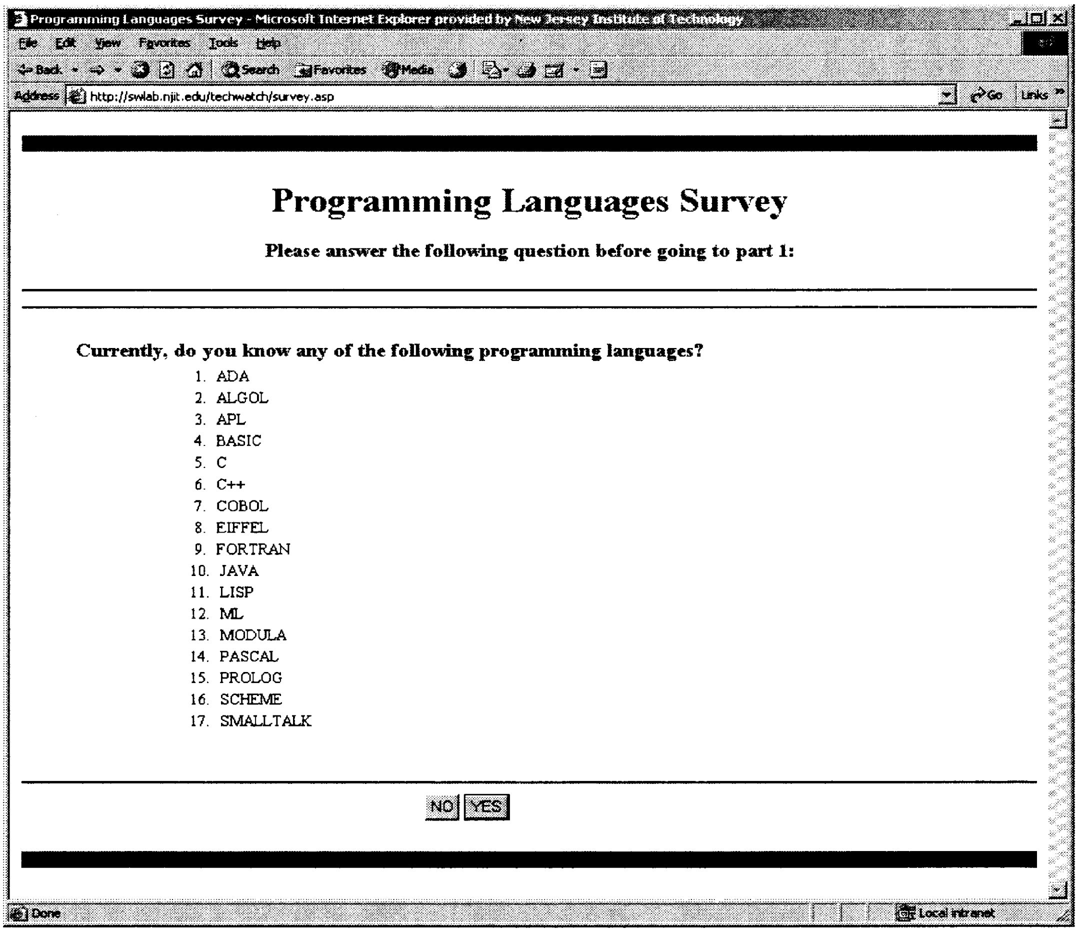
After studying the trends of programming languages, the other fields of software engineering will be done in near future. For example: the trends of operating system, the trends of networking, the trends of database, etc. All of these trends will use the similar methods to analyze. Generally, empirical method will be used first. After having better understanding of trends behavior, analytical method will used for them to understand the cause/effect relationships.

APPENDIX A

WEB-BASED SURVEY

The Web-based Programming Languages Survey asks a particular set of questions to the user bout the programming languages, which the user has learnt. The system then stores the information given to it by the user. In the first step the system asks whether the user knows at-least any one of the following Programming Languages:

ADA, ALGOL, APL, BASIC, C, C++, COBOL, EIFFEL, FORTRAN, JAVA, LISP, ML, MODULA, PASCAL, PROLOG, SCHEME and SMALLTALK.



Programming Languages Survey - Microsoft Internet Explorer provided by New Jersey Institute of Technology
File Edit View Favorites Tools Help
Back
Search
Favorites
Media
Address http://swlab.njit.edu/techwatch/survey.asp
Go
Links
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Local intranet

Programming Languages Survey

Please answer the following question before going to part 1:

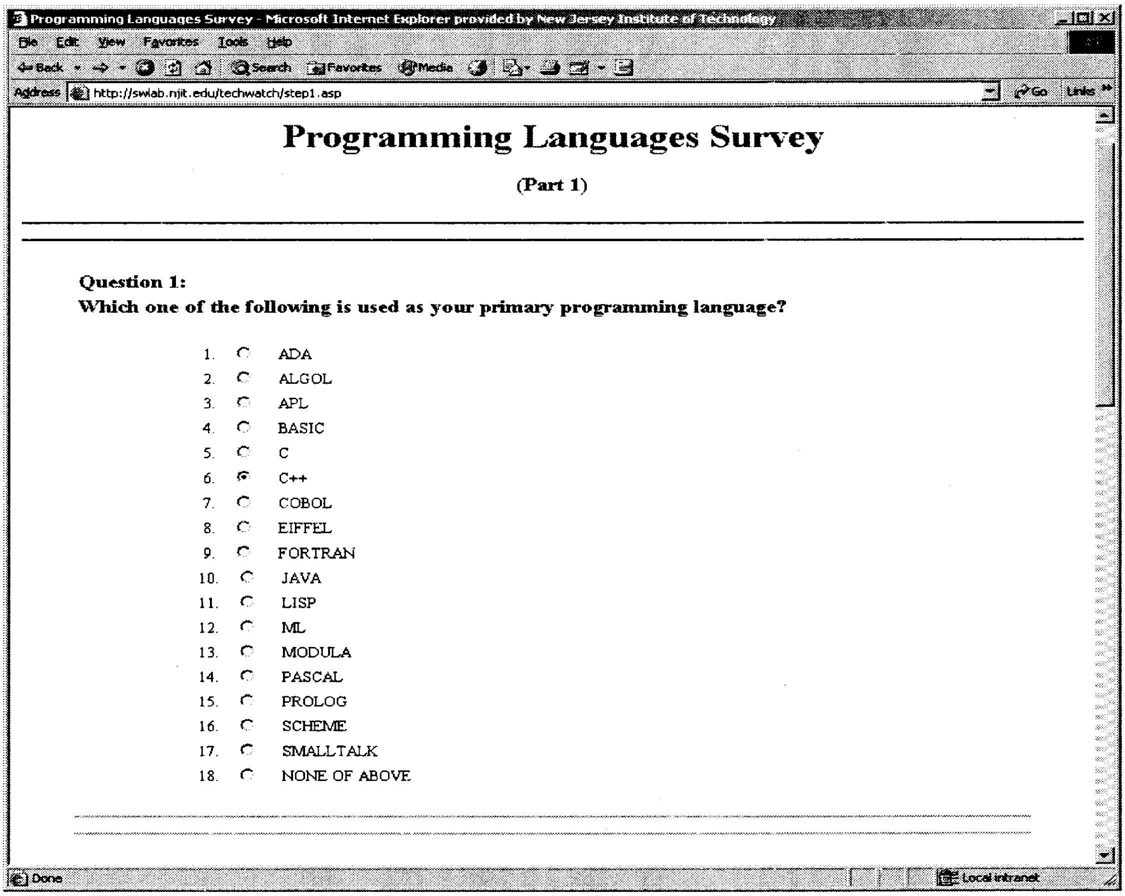
Currently, do you know any of the following programming languages?

1. ADA
2. ALGOL
3. APL
4. BASIC
5. C
6. C++
7. COBOL
8. EIFFEL
9. FORTRAN
10. JAVA
11. LISP
12. ML
13. MODULA
14. PASCAL
15. PROLOG
16. SCHEME
17. SMALLTALK

Figure A.1 Web-based programming languages survey.

If user chooses YES, the page that contains the first part of the survey is displayed. If the user selects NO, the survey ends by thanking the user for participation. At any point in the course of the survey the user can return back to the previous screen to modify the input. Programming Languages Survey asks several questions for 2003, 1998, and 1993.

In the first question, user is asked to select his/her primary programming language from a given set of seventeen programming languages. User can choose only one language from the seventeen languages, which he/she considers as primary programming language. If the user is not familiar with any of the languages then he/she can opt for the choice "None of the above".


Programming Languages Survey - Microsoft Internet Explorer provided by New Jersey Institute of Technology
File Edit View Favorites Tools Help
Back Search Favorites Media
Address http://swlab.njit.edu/techwatch/step1.asp
Go Links
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Local intranet

Programming Languages Survey

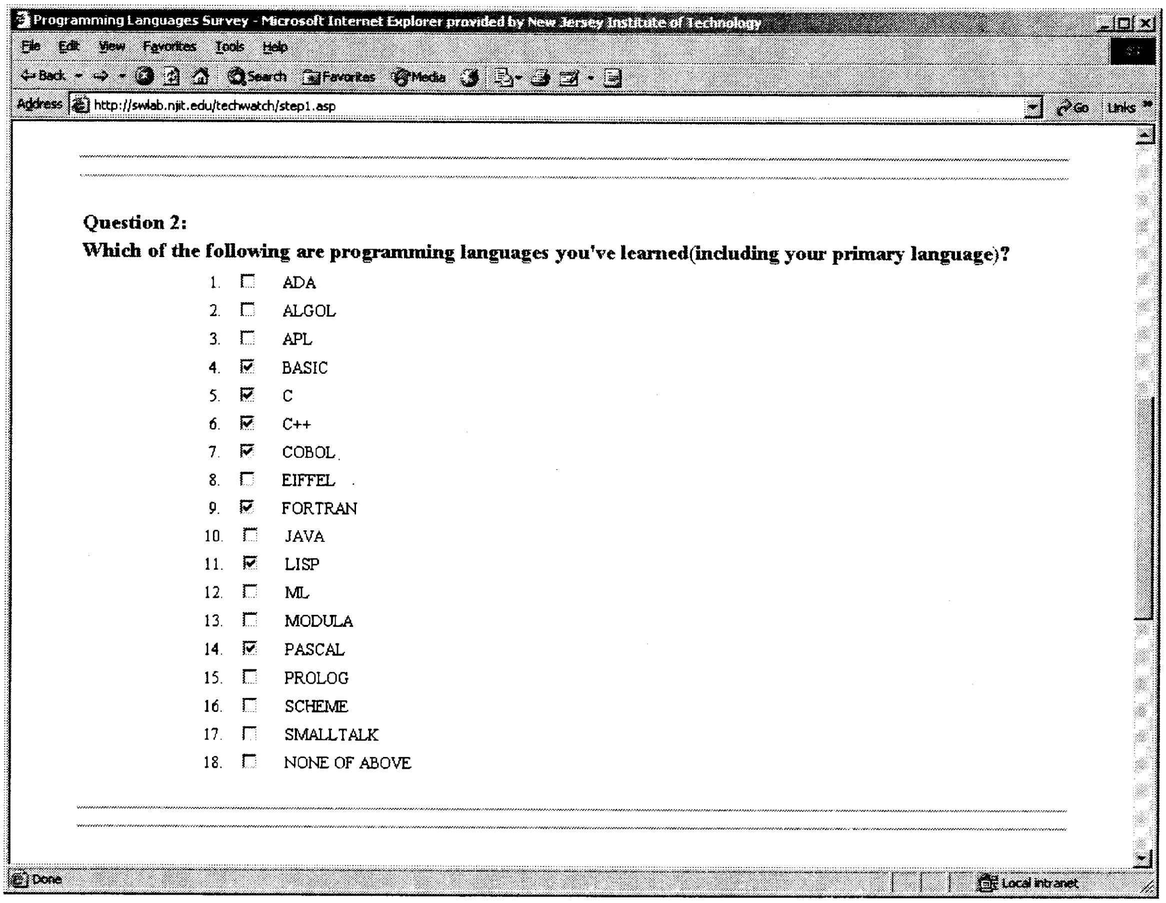
(Part 1)

Question 1:
Which one of the following is used as your primary programming language?

1. ○ ADA
2. ○ ALGOL
3. ○ APL
4. ○ BASIC
5. ○ C
6. ● C++
7. ○ COBOL
8. ○ EIFFEL
9. ○ FORTRAN
10. ○ JAVA
11. ○ LISP
12. ○ ML
13. ○ MODULA
14. ○ PASCAL
15. ○ PROLOG
16. ○ SCHEME
17. ○ SMALLTALK
18. ○ NONE OF ABOVE

Figure A.2 Sample survey question 1.

In the second question, user will be asked to select all the languages, which he/she has learnt. Unlike the first question, user can select multiple languages indicating all the languages which the user has learnt. If user had not learnt any of the languages, he/she can also select the choice "None of the above" as in the previous question.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File Edit View Favorites Tools Help
Back Search Favorites Media
Address http://swlab.njit.edu/techwatch/step1.asp
Go Links
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Local intranet

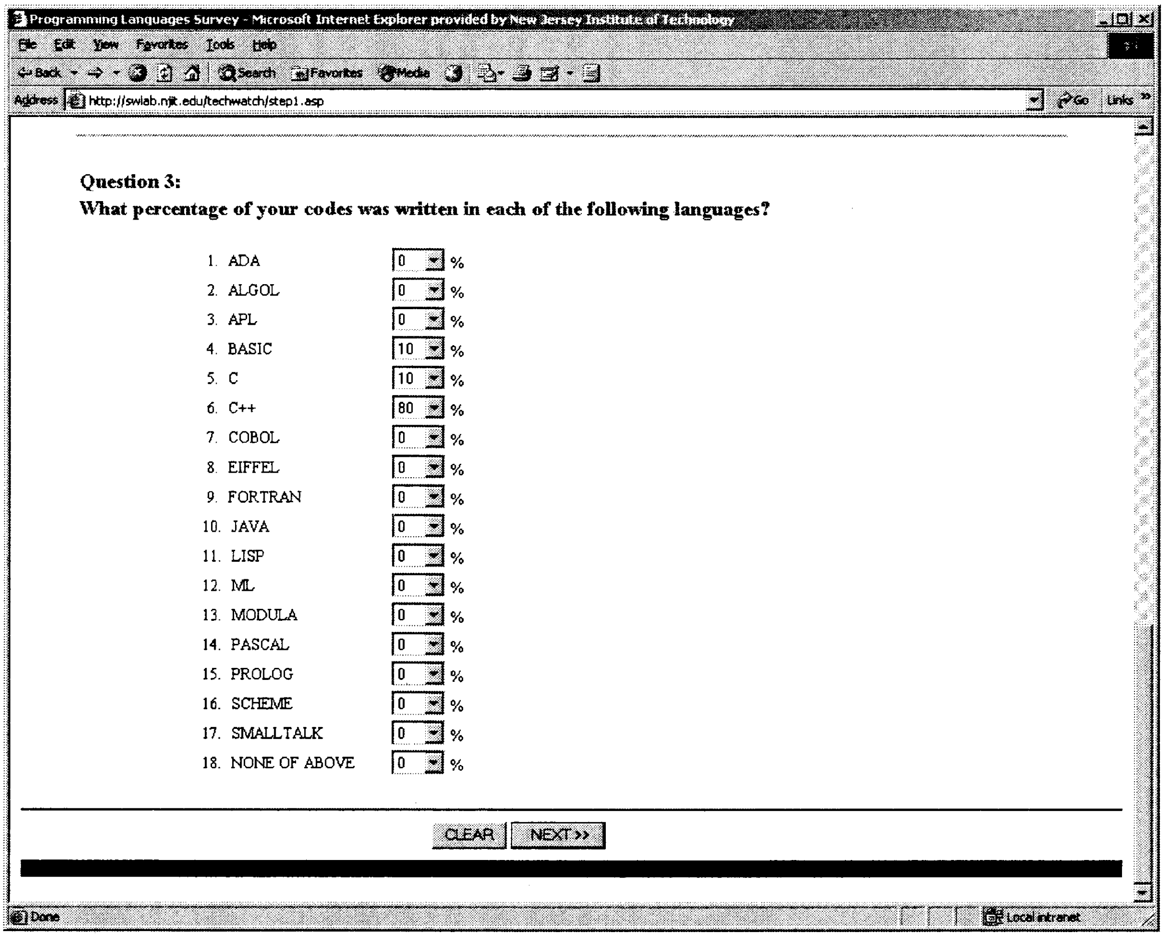
Question 2:
Which of the following are programming languages you've learned(including your primary language)?

1. ☐ ADA
2. ☐ ALGOL
3. ☐ APL
4. ☑ BASIC
5. ☑ C
6. ☑ C++
7. ☑ COBOL
8. ☐ EIFFEL
9. ☑ FORTRAN
10. ☐ JAVA
11. ☑ LISP
12. ☐ ML
13. ☐ MODULA
14. ☑ PASCAL
15. ☐ PROLOG
16. ☐ SCHEME
17. ☐ SMALLTALK
18. ☐ NONE OF ABOVE

Figure A.3 Sample survey question 2.

In the third question, user is asked to select the percentage of code, which he/she has written in all the languages. User must mark the approximate percentage of code written in all the languages he/she has programmed. The total percentage of code given by the user for all the programming languages must sum up to 100%. If not, there will be a failing message which requests user to fill again till the total is exactly 100%.

If user has not programmed in any of the languages displayed, then he/she can select the choice "None of the above" and give 100% in that box.


Programming Languages Survey - Microsoft Internet Explorer provided by New Jersey Institute of Technology
File Edit View Favorites Tools Help
Back Search Favorites Media
Address http://swlab.njit.edu/techwatch/step1.asp
Go Links
CLEAR
NEXT >>
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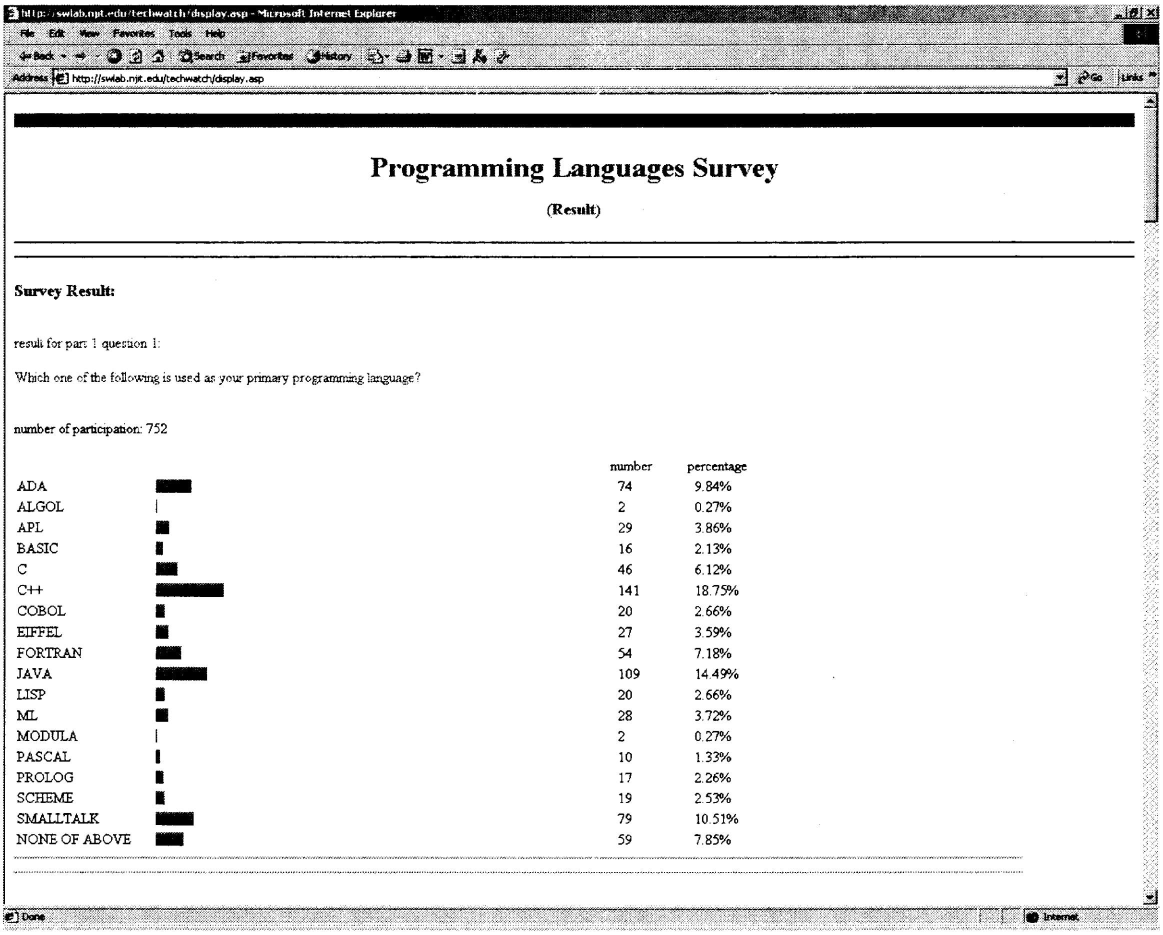
Local intranet

Question 3:
What percentage of your codes was written in each of the following languages?

1. ADA	0 %
2. ALGOL	0 %
3. APL	0 %
4. BASIC	10 %
5. C	10 %
6. C++	80 %
7. COBOL	0 %
8. EIFFEL	0 %
9. FORTRAN	0 %
10. JAVA	0 %
11. LISP	0 %
12. ML	0 %
13. MODULA	0 %
14. PASCAL	0 %
15. PROLOG	0 %
16. SCHEME	0 %
17. SMALLTALK	0 %
18. NONE OF ABOVE	0 %

Figure A.4 Sample survey question 3.

After getting the inputs for all questions from the user, the system stores user inputs and thanks for taking part in the survey. Figure A.5 shows a sample results we get from this web-base survey for programming language trends.


http://swlab.njit.edu/techwatch/display.asp - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Search Favorites History
Address http://swlab.njit.edu/techwatch/display.asp
Go Links
Done
Internet

Programming Languages Survey

(Result)

Survey Result:

result for part 1 question 1:

Which one of the following is used as your primary programming language?

number of participation: 752

	number	percentage
ADA	74	9.84%
ALGOL	2	0.27%
APL	29	3.86%
BASIC	16	2.13%
C	46	6.12%
C++	141	18.75%
COBOL	20	2.66%
EIFFEL	27	3.59%
FORTRAN	54	7.18%
JAVA	109	14.49%
LISP	20	2.66%
ML	28	3.72%
MODULA	2	0.27%
PASCAL	10	1.33%
PROLOG	17	2.26%
SCHEME	19	2.53%
SMALLTALK	79	10.51%
NONE OF ABOVE	59	7.85%

Figure A.5 Survey results.

APPENDIX B

PREDICTIVE MODEL SIMULATION

1. Functions Performed

1.1 Language Selection

The web-based predictive model for programming language trends allows users to select the desired programming languages and see what are the future trends for these programming languages. Users are also allowed to make a selection of any language from a given set of programming languages:

ADA, ALGOL, APL, BASIC, C, C++, COBOL, EIFFEL, FORTRAN, JAVA, LISP, ML, MODULA, PASCAL, PROLOG, SCHEME, and SMALLTALK

Once user selects one of the above languages, the selected programming language will be used throughout the session for input, calculations and prediction. Users have opted to use the model for the selected language for the current session.

At any point during the session of the application, the user can choose to return to language selection page, and restart the whole process by selecting a different programming language. Users can also change the internal value of a language to create their own user-defined programming languages.

1.2 Display Factors

After users have made a choice for a particular language, this feature allows the users to view the factors (parameters) of the selected language. The values for the following factors of a language will be displayed.

Intrinsic Factors:

Generality

Orthogonality

Reliability

Maintainability

Efficiency

Simplicity

Implementability

Machine Independence

Extensibility

Expressiveness

Influence/Impact

Extrinsic Factors

For Extrinsic Factors the values will be displayed in groups:

Grassroots Support

How many people consider this Language their primary programming Language?

How many people know this language?

How many percentage of code is written in this language?

How many user groups dedicated in this language?

Governmental Support:

Is this language introduced by any government/agency?

How many government standards for this language?

How much code is written by government in this language? (in million)

Industrial Support:

Is this language introduced and supported by any Company?

How many companies use this language as primary language to develop products?

How many developers consider this language as their primary language?

How many companies use this language as support for any of their products?

How many developers know about this language?

How many commercial applications are developed by using this language?

Institutional Support:

Is this language introduced and supported by any institution?

How many institutions use this language as the support for introductory programming courses?

How many students have used this language for their introductory programming courses?

How many institutions use this language as the support for any courses?

How many students have used this language for any of their courses?

How many research projects use this language as support?

How many research projects deal with this language as subject?

Organizational Support:

Is this Language Introduced by an Organization?

Is this Language Supported by an Organization?

Does this Language have any standards?

Number of Conferences of this Language

Number of Papers/Articles on this Language

Number of Papers/Articles using this Language

Technology Support:

How many compilers/Interpreters are available for this language?

How many debuggers are available for this language?

How many IDEs/CASE tools available for this language?

How many libraries (including third-party libraries) are available for this language?

How many operating systems support this language?

The values displayed are the default values from the data warehouse.

1.3 Updating Factors

User is allowed to make changes, if desired, to the default factor values that are displayed from the database. This functionality allows the user to adjust or tune the value of any parameter and see the effect this change would have on the projected results from the statistical model. Thus, the user can test several combinations of factor parameters and see the projected results from the combinations.

1.4 Year Selection

User is allowed to select the year for which the projection for the language has to be calculated. The year of projection needs to be selected from a list of years, which is from the next year till the year 2008. Once the user makes the selection for the year, the calculations of prediction will be done for the extrinsic factors of this particular programming language in that particular year.

1.5 View Results

After making a language selection, viewing and updating the factors (parameters) of a programming language, and selecting the year to do prediction for, users can choose to view the predictive results for this language in the chosen year. The system takes the inputs that the user has provided thus far and calculates the projections for the extrinsic factors of the language for the selected year. These calculations are done based on formulas derived from the multivariate multiple regression model. For example, to predict the values for an extrinsic factor in the year of 2008, a formula like the following will be used:

$$E_{2008} = A * I + B * E_{2003} + C * E_{1998}$$

Where

E_{2008} = Extrinsic factor for the year 2008

I = Intrinsic factor for this language

E_{2003} = Extrinsic factor for the year 2003

E_{1998} = Extrinsic factor for the year 1998

A, B, C are parameter matrix

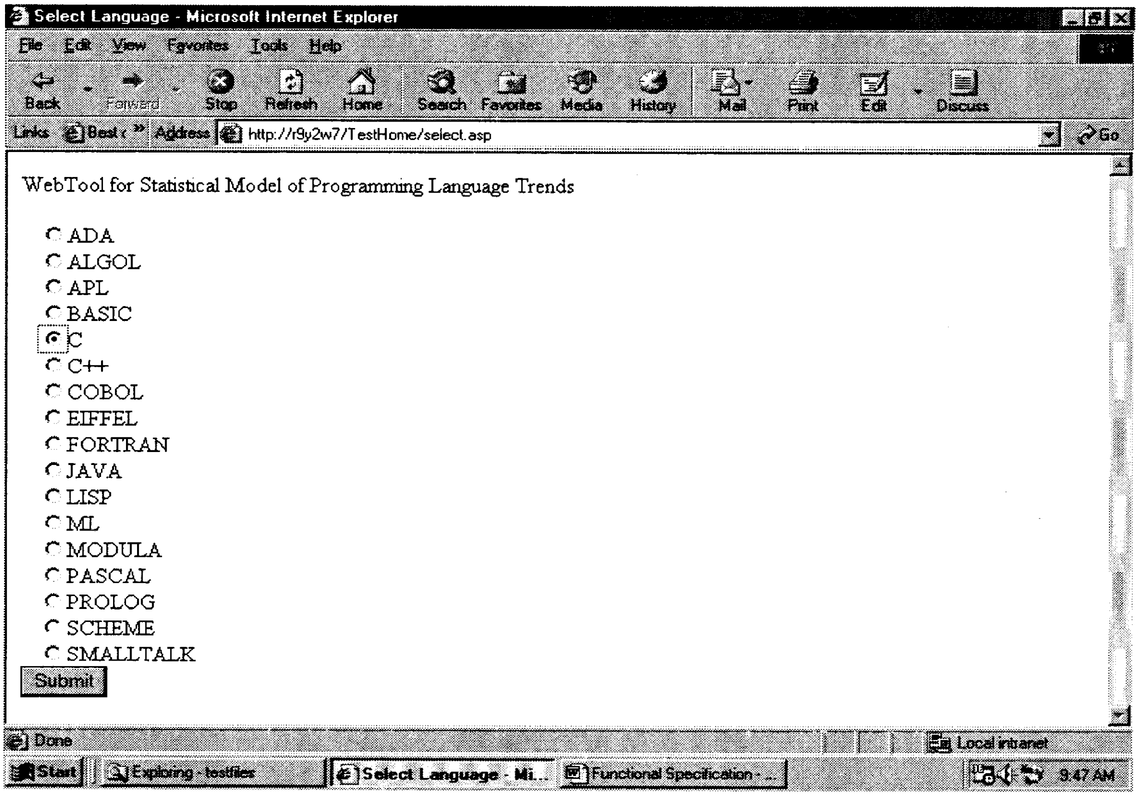
The predictive results are displayed according to the extrinsic factor groups.

1.6 View Graph

For each extrinsic factor of a programming language, the system provides the functionality to view the results of the prediction for the factor in a graphical representation. The graph displayed is a two-dimensional bar chart for the extrinsic factor selected. The X-Axis is a time line in years and has the years 1993, 1998, 2003 and the year of prediction selected The Y-Axis is the value of the extrinsic factor plotted to scale as a vertical bar in the graph. This graph helps in viewing the trends of the extrinsic factor over the years of displayed data.

2. User Interface

2.1 Language Selection


Select Language - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Forward Stop Refresh Home Search Favorites Media History Mail Print Edit Discuss
Links Best (» Address
Go
Submit
Done
Local intranet
Start Exploring - testfiles Select Language - Mi... Functional Specification - ...
9:47 AM

http://r9y2w7/TestHome/select.asp

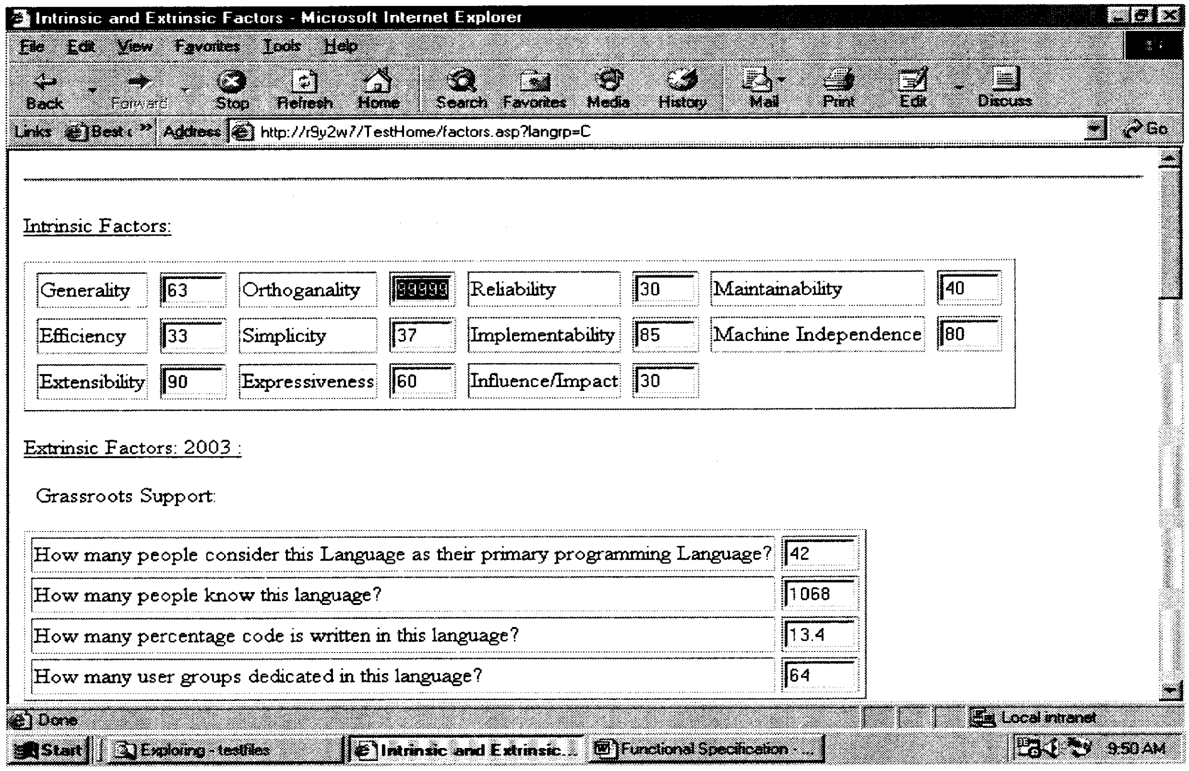
WebTool for Statistical Model of Programming Language Trends

○ ADA
○ ALGOL
○ APL
○ BASIC
● C
○ C++
○ COBOL
○ EIFFEL
○ FORTRAN
○ JAVA
○ LISP
○ ML
○ MODULA
○ PASCAL
○ PROLOG
○ SCHEME
○ SMALLTALK

Figure B.1 Language selection.

The first step in the process of using the tool is choosing the language. The graph above is the layout of the web page for language selection. User can select the language from a list using the radio button control and register the selection using the submit button control, which passes the selection into the next step. As shown above in Figure B.1, user has made the selection of C programming language.

2.2 Viewing and Updating Factors


Intrinsic and Extrinsic Factors - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Forward Stop Refresh Home Search Favorites Media History Mail Print Edit Discuss
Links Best » Address
Go
Done
Local intranet
Start
Exploring - testfiles
Intrinsic and Extrinsic...
Functional Specification - ...
9:50 AM

http://r9y2w7/TestHome/factors.asp?langrp=C

Intrinsic Factors:

Generality	63	Orthoganality	99999	Reliability	30	Maintainability	40
Efficiency	33	Simplicity	37	Implementability	85	Machine Independence	80
Extensibility	90	Expressiveness	60	Influence/Impact	30		

Extrinsic Factors: 2003 :

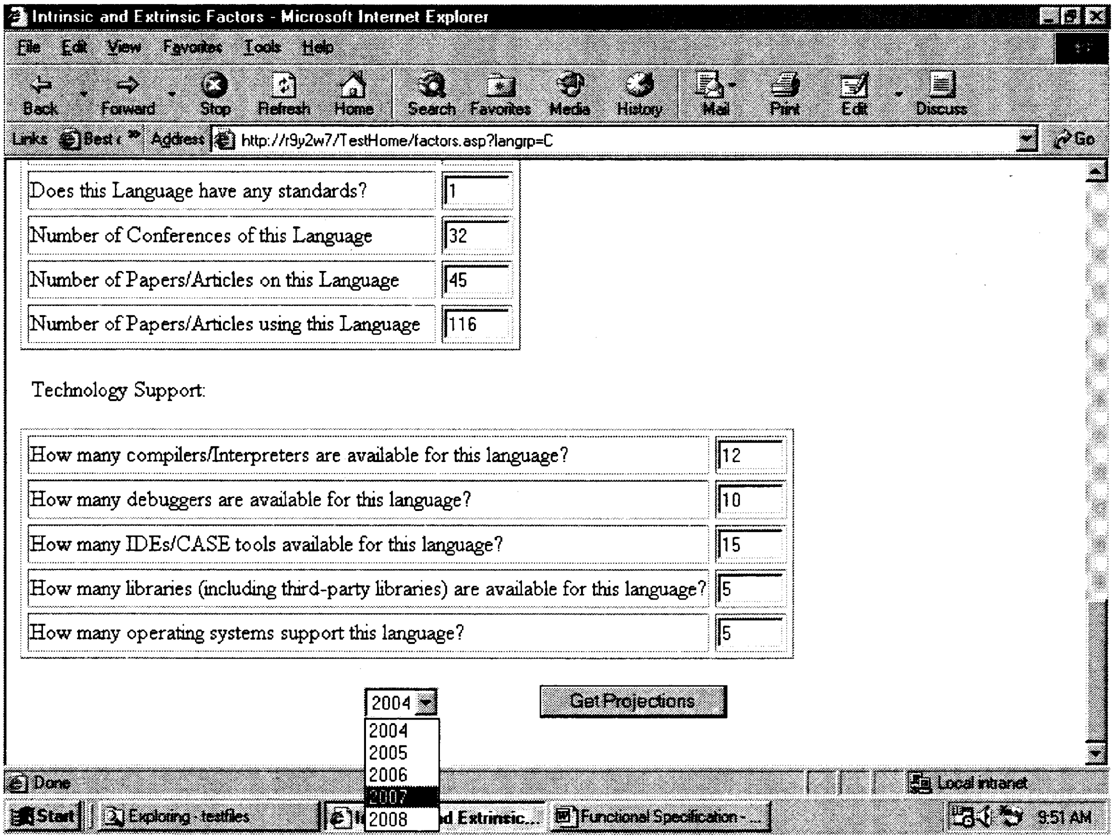
Grassroots Support:

How many people consider this Language as their primary programming Language?	42
How many people know this language?	1068
How many percentage code is written in this language?	13.4
How many user groups dedicated in this language?	64

Figure B.2 Language factors.

The above layout shows the web page for displaying the intrinsic and extrinsic factor values for the language selected in the previous page. The Intrinsic factors are listed in a table, followed by extrinsic factors in separate table group-wise. The values are shown in text box controls and user can edit the values displayed. As shown above in Figure B.2, the user is changing the value of the Orthoganality.

2.3 Prediction Year Selection


Intrinsic and Extrinsic Factors - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Forward Stop Refresh Home Search Favorites Media History Mail Print Edit Discuss
Links Best « Address http://r9y2w7/TestHome/factors.asp?langrp=C Go
Done
Local intranet
Start Exploring - testfiles Intrinsic and Extrinsic... Functional Specification - ...
9:51 AM
Get Projections

Does this Language have any standards?	1
Number of Conferences of this Language	32
Number of Papers/Articles on this Language	45
Number of Papers/Articles using this Language	116

Technology Support:

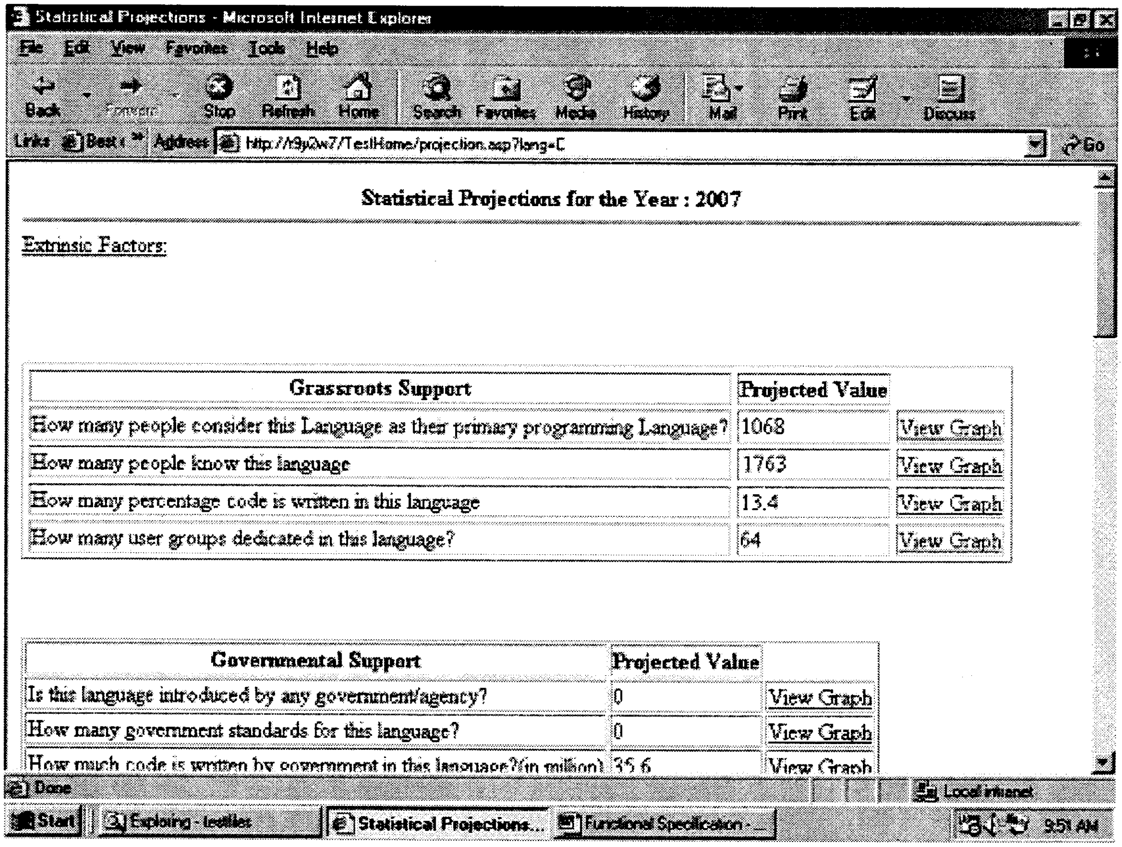
How many compilers/Interpreters are available for this language?	12
How many debuggers are available for this language?	10
How many IDEs/CASE tools available for this language?	15
How many libraries (including third-party libraries) are available for this language?	5
How many operating systems support this language?	5

2004
2004
2005
2006
2007
2008

Figure B.3 Projection year.

This is the layout for the year selection implemented as a drop down list control. As shown above in Figure B.3, user can select the year for which the predictions of factors for a selected language are desired. The figure shows that user has selected the year of 2007 from the drop down list of Years.

2.4 Prediction Results


Statistical Projections - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Forward Stop Refresh Home Search Favorites Media History Mail Print Edit Discuss
Links Best » Address http://t9y2w7/TestHome/projection.asp?lang=C Go
Done
Local intranet
Start Exploring - testfiles Statistical Projections... Functional Specification - ...
9:51 AM

Statistical Projections for the Year : 2007

Extrinsic Factors:

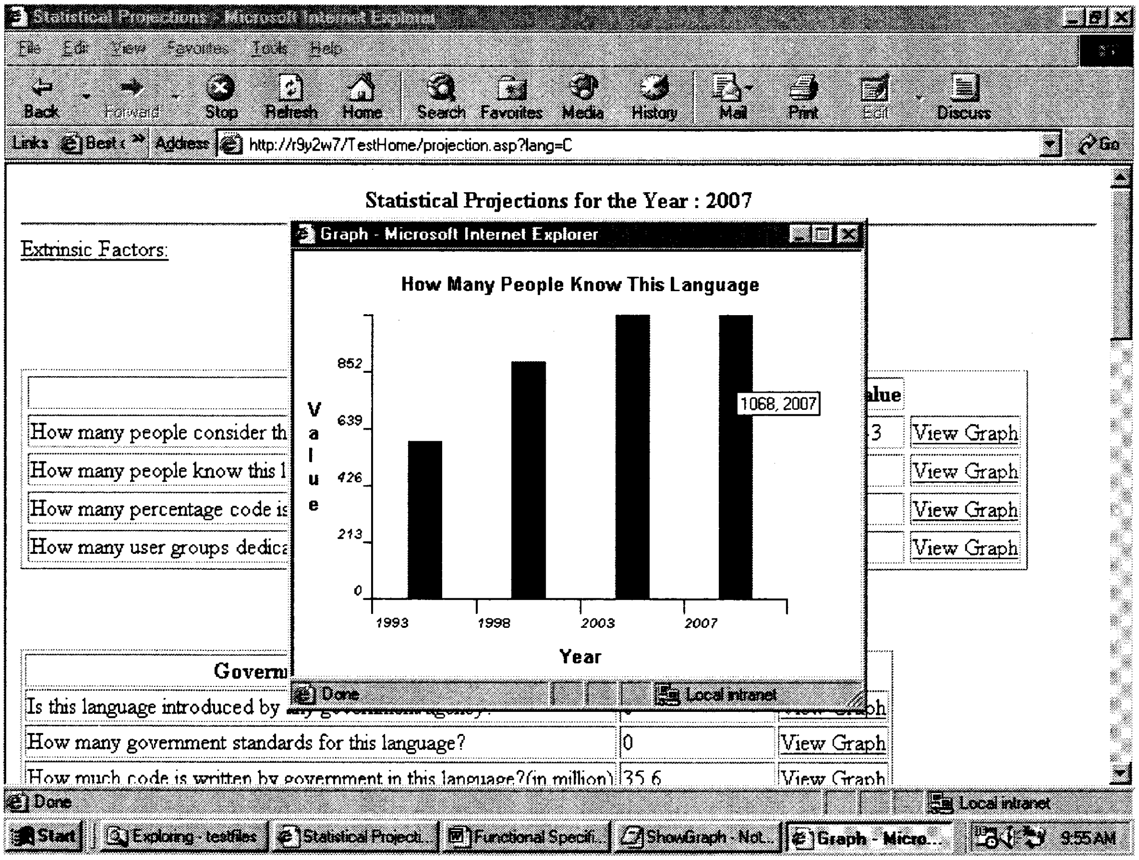
Grassroots Support	Projected Value	
How many people consider this Language as their primary programming Language?	1068	View Graph
How many people know this language	1763	View Graph
How many percentage code is written in this language	13.4	View Graph
How many user groups dedicated in this language?	64	View Graph

Governmental Support	Projected Value	
Is this language introduced by any government/agency?	0	View Graph
How many government standards for this language?	0	View Graph
How much code is written by government in this language?(in million)	35.6	View Graph

Figure B.4 Projection results.

The above Figure B.4 is the web page layout of the results or output page of the model simulation program. The layout shows the projection results of the extrinsic factors of the language for the year selected previously. The values are shown as simple text in tabular format.

2.5 View Prediction Graph


Statistical Projections - Microsoft Internet Explorer
File Edit View Favorites Tools Help
Back Forward Stop Refresh Home Search Favorites Media History Mail Print Edit Discuss
Links Best » Address http://r9y2w7/TestHome/projection.asp?lang=C
Go
Graph - Microsoft Internet Explorer
How Many People Know This Language
852
639
426
213
0
Value
1068, 2007
1993
1998
2003
2007
Year
Done
Local intranet
Start
Exploring - testfiles
Statistical Projecti...
Functional Specifi...
ShowGraph - Not...
Graph - Micro...
9:55 AM

Statistical Projections for the Year : 2007

Extrinsic Factors:

	alue	
How many people consider th	3	View Graph
How many people know this l		View Graph
How many percentage code is		View Graph
How many user groups dedica		View Graph

Governm		
Is this language introduced by		h
How many government standards for this language?	0	View Graph
How much code is written by government in this language?(in million)	35.6	View Graph

Figure B.5 Prediction graph

The above Figure B.5 is the layout design of viewing the results of prediction in graphical format. The trend graph for a particular extrinsic factor can be viewed from the projection results using the link "View Graph" provided next to the displayed projected value of the factor. The Graph is a bar graph in a new window. Figure B.5 shows the graph chart for the Grassroots Support factor "How Many People know this language" As shown, moving the cursor on the bar line shows the coordinates in numerical format.

Moving the cursor on the last bar line is showing the value in the chart for that bar as (1068,2007).

3. Data Warehouse

The data that used for projection calculations was collected through surveys and organized in an accessible format. For accessing this data from the web-based model, the data is referenced from a set of Microsoft excel files stored on the web server. For intrinsic factors, we have the following files:

The IntrinsicFactors.xls file has rows for each language of our set of languages and the columns represent the Intrinsic Factors. Thus accessing the cell of the excel file corresponding to a particular row and column gives us the value for that intrinsic factor for the corresponding language.

Each of the extrinsic factor files is organized into 3 sheets of data, one each for the years 1993, 1998 and 2003. The rows in each sheet are the languages from our set of languages for which data was collected. The columns represent the extrinsic factor within the particular group like Grassroots Support, etc. For ease of accessing extrinsic factors for use in calculations of projections, the column headings for the factors have been changed to the variable names used in the regression formulas. Thus we can access the cell corresponding to the language name and variable name for the Extrinsic factor to get the value to use in the Regression Formula for calculations.

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