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A SOFTWARE TOOL TO DISPLAY MESSAGE SEQUENCE CHARTS

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A Major Report

in

The Department

of

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ABSTRACT

A Software Tool to Display Message Sequence Charts

Xiaoming Tang

Message Sequence Charts (MSC) is a trace language. It is widely used to show sequences of messages interchanged between system components and their environment. It is gaining popularity in software engineering methods for concurrent and real-time systems. MSC has been standardized by the ITU-T (International Telecommunication Union, Telecommunication Standardization Sector of ITU) in Recommendation Z.120 since 1992. A new revised standard Z.120 (MSC96) was approved by ITU-T in 1996. MSC includes two syntactical forms, MSC/PR as a pure textual and MSC/GR as a graphical representation. An MSC in MSC/GR representation can be transformed automatically into a corresponding MSC/PR representation. However, the reverse way is difficult since MSC/PR does not include graphical information such as height, width of symbols and texts. This report presents a software tool to convert a textual description into an internal representation, then to display the graphical representation. The object structure built in this software can be used in the further studying or analyzing of MSC96.

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Chapter 1 Introduction

Message Sequence Charts (MSC) can be viewed as a special trace language that shows the sequence of messages interchanged between communication entities and their environment. The communication entities are modeled as SDL services, processes and blocks [1]. The MSC includes two syntactical forms, MSC/PR and MSC/GR. MSC/PR is a pure textual representation and MSC/GR is a graphical representation [7]. The word MSC sometimes is used to refer to a single Message Sequence Chart. A single Message Sequence Chart is used to document a single system, which may be a sub-system of the system. A Message Sequence Chart is not a description of the complete behavior of the whole system. It usually covers a partial behavior and merely expresses the execution trace [2].

Message Sequence Chart's (MSC) main applications is in the area of telecommunication systems [4]. However, its usage is not restricted to only telecommunications. MSC is increasing its popularity within the software engineering community [3]. MSC has already been adopted by several software engineering methodologies and tools. For example: MSC can be used in the use case model. In the use case model, the user and server can be viewed as **instances** in the MSC. The user's request or action can be viewed as a **message** sent to the server, and the server's response can be viewed as a **message** sent back. The trace of the system can be documented as a MSC. The different scenarios can be represented by the **inline** construct or by high level Message Sequence Chart [5].

Analysis and documentation of a complex system is a crucial and a non-trivial task. MSC can make this kind of task easy. The main advantage of an MSC is its clear

graphical layout that immediately gives an intuitive understanding of the described system behavior. Firstly, MSC can be used in the software requirement stage to document the system [4,6]. It is used to visualize sample behavior of a simulated system specification [4]. Secondly, MSC is used to guide software design, describe the test cases and scenarios in the test stage. Furthermore, MSC can be used to express system properties in the verification stage and in the interface specification. Also, MSC is helpful in software maintenance and reengineering [4,5,6].

MSC has matured within a very short period of time to become a considerably powerful and expressive language [6]. At the beginning, MSC was used merely as an informal and illustrative language. Then it advanced to a formal and descriptive language [6,7]. The International Telecommunication Union (ITU, former CCITT) approved the first MSC recommendation Z.120 in 1992 [2]. A formal syntax and semantics for MSC has been standardized in the Z.120. That increased the usage and popularity of the MSC language. MSC'92 was influenced very much by the idea coming from Petri Nets with its composition mechanisms based on conditions [7]. However, the language constructs defined in MSC'92 are not sufficient to describe an information system comprehensively. MSC'92 has to be used in combination with other languages like SDL. Thus, the study group of ITU developed corresponding formal semantics based on process algebra [6]. Then ITU approved the new standardization of MSC, which is MSC'96 [1]. MSC'96 becomes a powerful synthesis of concepts taken from process algebra, Petri Nets, and from object oriented modeling [6]. The object-oriented community has shown interest in using MSC. Now, it is even under discussion within the "Unified Method for Object Oriented Development" [13].

The standardization of MSC by ITU makes it possible to provide tools to support it, to exchange MSCs between different tools and to ease the mapping to and from SDL specifications. Many tools are built for this purpose. One example is ObjectGEODE. ObjectGEODE is a software that user can draw and edit a MSC/GR. The elements of the graph are the elements of MSC. ObjectGEODE can transfer the graphic MSC into the textual MSC [15]. However most of those tools are graphical editors based on MSC/GR. They transform an MSC from MSC/GR representation into a corresponding MSC/PR representation [7]. However, transforming an MSC from MSC/PR representation to MSC/GR representation is not so obvious since MSC/PR does not include graphical information such as height, width, or alignment of symbols and texts. One problem is displaying the MSC in the right position. MSC'96 has a very rich grammar, which supports both instance-oriented and event-oriented representations in MSC/PR. In instance-oriented representation, MSC is ordered by instance. And in event-oriented representations, events are listed in form of a possible execution trace. Event-oriented representation is preferable to describe the global ordering. It is closer to the graphical grammar. It is less ambiguity using event-oriented representations in the PR-GR transformation [7]. Mixture of above two syntaxes is allowed in MSC'96. That makes it even harder to transfer a textual MSC to a graphical MSC.

The MSC/PRs are not only used internally by tools, but also edited by human [7]. The MSC is used frequently in connection with the SDL language. The MSC/PR can be analyzed by SDL tools in the cases of validation, tracing, debugging, simulation and test case specification [1,4,6,14]. Also MSC/PR is easy to be convert to process algebra, and to be modified, adjusted during the analysis. So transformation of MSC/PR to MSC/GR

is important to visually observe the results of modification. Although there is GIF(Graphic Interchange Format), which is a standardized graphic format, for the exchange between different tools, it is basically display the same graphic under different tools, specially in the web site. It is not easy to transfer the element in the graphic as object. Thus, using MSC/PR to exchange and edit between different tools is easy. What do we need is that there are tools to analysis the syntax and semantic of MSC/PR and represent it in MSC/GR.

This paper presents a new software tool, which transfers a textual representation of MSC (MSC/PR) to a graphic representation (MSC/GR). This software will read the textual representation of MSC, analyze it and build a network of objects of class to represent it, then display them graphically.

Chapter 2 briefly reviews the syntax and semantics of a basic MSC and high-level MSC. It also reviews the Microsoft Visual C++ that the software is based on. Chapter 3 describes the design including assumptions, overview, and detail. Chapter 4 provides conclusions, covers some issues of further work, and describes the experience that I have learned. Appendix A presents the grammar of MSC. Appendix B presents the tokens used in the parser. Appendix C presents the C functions of the project. Appendix D presents the classes of the project.

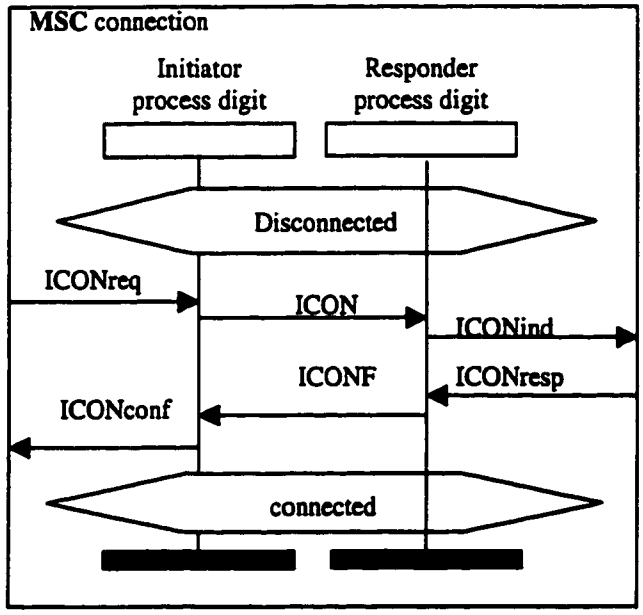
Chapter 2 Background Knowledge

Message Sequence Charts (MSC) is graphical specification formalism. It focuses on the messages interchanged between communication entities and their environment. As mentioned in the introduction, the use of MSC has evolved from describing and visualizing sample, finite system runs and test cases as basic MSC, to describing the behavior of complex system in a modular and hierarchical fashion as high-level MSC [3]. In the first section of this chapter, we review the specification of basic MSC. In the second section we describe the high level MSC. The third section is about our deviation from standard MSC/PR.

Microsoft Visual C++ is a popular software package for programming under Microsoft Windows in PC environment [8]. It also can be used as a C/C++ compiler for writing C/C++ programs under PC platform. The Microsoft Foundation Class (MFC) library has a set of powerful tools to create applications for Windows [10]. In the section 4, a brief review of MFC is given.

2.1 Basic Message Sequence Charts

Basic MSC describes a partial behavior of a system. It describes the finite executions of the processes in the system [1]. Figure 1 shows an example describing a successful connection case. The left side of the figure is MSC/GR. And the right side is MSC/PR




```
msc connection;
inst Initiator, Responder;
 instance Initiator: process digit;
  condition Disconnected
       shared Responder;
  in ICONreq from env;
  out ICON to Responder;
  in ICONF from Responder;
  out ICONconf to env;
  condition connected
       shared Responder;
 endinstance;
 instance Responder: process digit;
  condition Disconnected
       shared Initiator;
  in ICON from Initiator;
  out ICONind to env;
  in ICONresp from env;
  out ICONF to Initiator;
  condition connected
       shared Initiator;
 endinstance;
endmsc;
```

Figure 1 A MSC example in MSC/GR and MSC/PR

Basic MSC contains all constructs that are essential to specify the message flow. Those constructs are **instance, message, environment, gate, condition, action, timer, instance creation**, and **instance stop** [7]. The most important construct is **instance** [2], which is represented as a vertical line delimited by a start and an end in the Figure 1. An **instance** of an entity is an object of the entity. An entity can be a process, a block, a system or a service. An entity name may be specified for the **instance**. In Figure 1, **instance** "Initiator" is an object of entity "process digit".

In MSC/GR each horizontal or sloping arrow represents a **message**. A tail of the arrow denotes the event message sending. The head denotes the event message consumption. In the MSC/PR, a message inter-change between two instances is split into two events: the message input denoted by keyword **in**, and message output denoted by keyword **out**. A **message** has a name and may have parameters. A message can be sent to "lost", which means it is not consumed. Or a message can be received from "found", which means it appears from nowhere.

The system environment is represented by the frame symbol of MSC, that is, the boundary of the diagram, in MSC/GR, and by the keyword **env** in MSC/PR. The **environment** can send or receive messages. In Figure 1, **instance** "Initiator" receives message "ICONreq" from the environment and then sends "ICON" to **instance** "Responder".

A **gate** represents the interface between MSC and its environment. A message sent to the **environment** or received from the **environment** is associated with a **gate**. A **gate** name can be implicitly or explicitly given. The explicit **gate** name will appear on the diagram of MSC/GR. In MSC/PR, all **gates** are defined in the interface by a **gate** list.

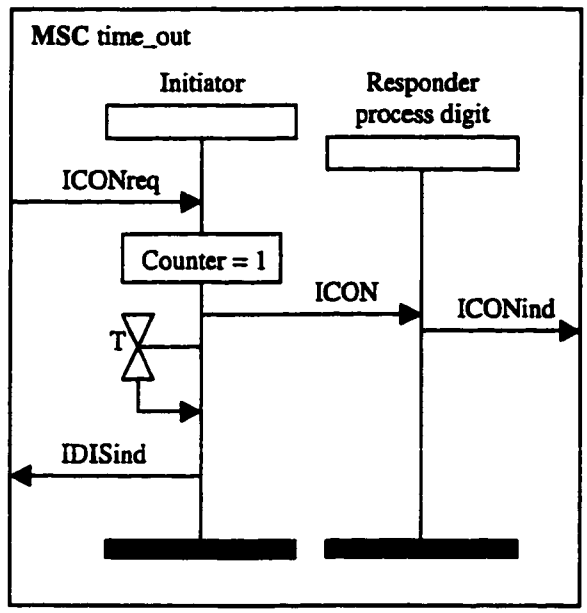
A **condition** describes the state of a non-empty set of **instances** of the MSC. When a **condition** refers to all the instances in the MSC, it describes the global state of the MSC. Otherwise it describes a non-global state. If it only refers to one **instance**, it describes the local state of the instance. In Figure 1, **condition** "Disconnected" is a global state that describes the initial state of the communication. A global condition can be an initial global condition, an intermediate global condition, or a final global condition. In

Figure 1, "connected" is the final condition. A **condition** is defined by the keyword **condition** in MSC/PR.

An **action** describes an internal activity of an instance. In MSC/GR, an **action** is a box that contains the text of the action. The keyword **action** is used in MSC/PR.

A **timer** is used to describe timer request, like time expiration, of an instance. Time expiration is represented though set a timer and a subsequence time out. Time supervision is represented though set a time and a subsequence reset timer. **Timer** is represented by an hourglass in MSC/GR. The keywords **set**, **reset**, and **timeout** are used in MSC/PR.

Using the **instance creation** and **instance stop** to represent a dynamic communication system. In such a system, an instance can appear and disappear during the run time. It can be created by another instance and terminate (stop) itself. The **instance creation** symbol in the MSC/GR is a dashed arrow from parent instance to the head of the child instance. The **instance stop** is a cross in the end of the instance axis. Only the instance created by another instance can stop itself. The keyword **create** and **stop** are used in MSC/PR. Figure 2 shows action, set timer and reset timer.




```
msc time_out;
inst Initiator, Responder;
 instance Initiator;
  in ICONreq from env;
  action 'counter = 1' ;
  out ICON to Responder;
  set T;
  timeout T;
  out IDISind to env;
 endinstance;
 instance Responder;
  in ICON from Initiator;
  out ICONind to env;
  endinstance;
endmsc;
```

Figure 2, MSC time_out in MSC/GR and MSC/PR

The order of one MSC is partial ordering. No ordering of message within **environment** is assumed. Within each **instance**, time is running from top to bottom; however no proper time scale is assumed. Also no global time axis is assumed for one MSC. The events along the **instance** axis are ordered (exception in high-lever MSC). Events of different **instances** are ordered via **message(s)** or via generalized ordering mechanism among the **orderable events** of difference **instances**. A message must be sent before it is consumed. In Figure 2, event "out ICON" is before "in ICON", so before "out ICONind". The **orderable events** are **message** event, **create instance**, **timer** events, and **action**. The keyword **before** and a label are used to specify the order in MSC/PR. In MSC/GR is an arrow connecting two events. Figure 3 shows the generalized ordering mechanism.

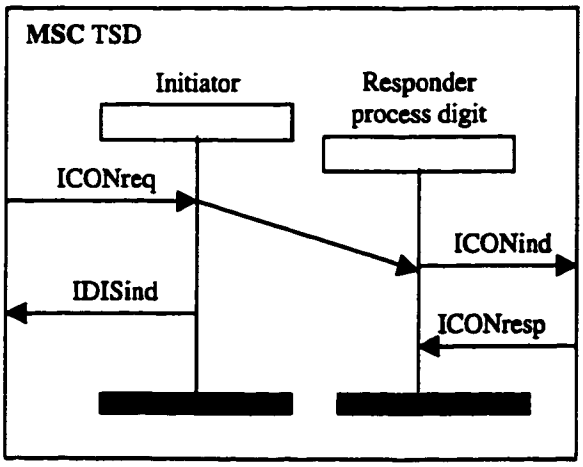
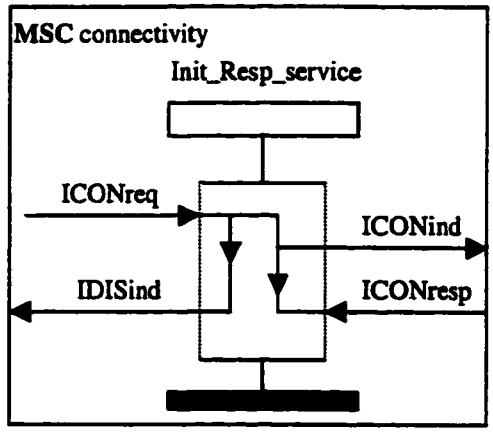


Figure 3, Ordering between two instances

2.2 MSC structure concept and high-level Message Sequence Charts

The structural language elements are introduced into MSC to specify more general MSC or refine MSC. Those elements are the generalized time ordering, composition and decomposition of instance, **MSC reference** and composition of events inside the MSC. Then **high level MSC** is added to MSC. **High level MSC** focuses completely on the composition aspects. It acts like a road map, which gives a very good characterization how individual MSC composed into an overall system [6]. The structural language elements are **coregion, instance decomposition, inline expression, MSC reference,** and **High-level MSC.**

Coregion is used to indict the non-deterministic period in one instance. It marked with starts (keyword **concurrent**) and ends (keyword **endconcurrent**). During this time period, event is unordered expect explicit ordering. The explicit ordering can be the generalized ordering mechanism mentioned above, or the timer which must be set before either reset or timeout. Figure 4 show a coregion with generalized ordering. The dashed instance axis is used to represent **coregion** in MSC/GR.




```
msc connectivity;
inst Init_Resp_service;
 concurrent;
  in ICONreq from env before label1, label2;
  label1 out ICONind to env before label3;
  label2 out IDISind to env;
  label3 in ICONresp from env;
 endconcurrent
endinstance;
endmsc
```

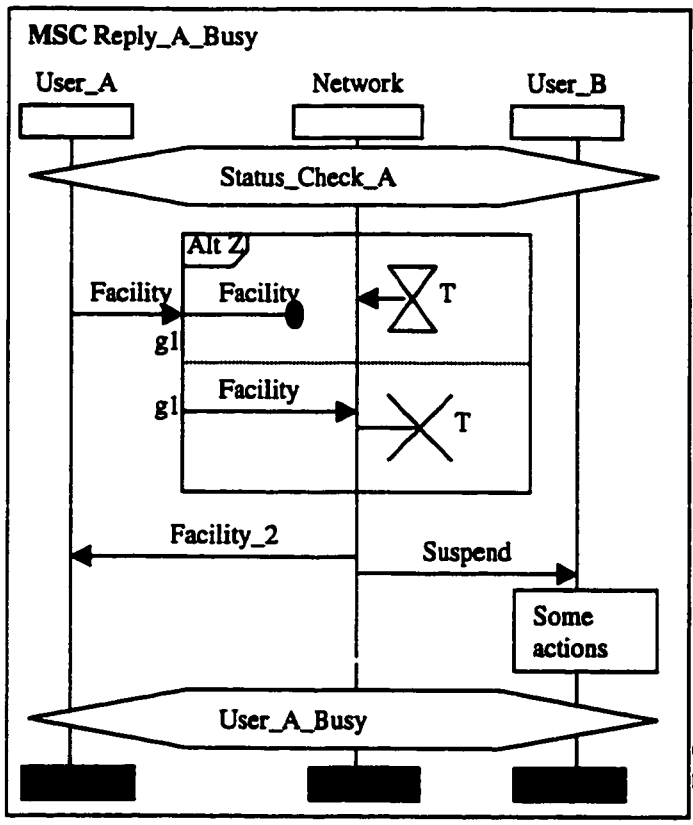
Figure 4, Coregion with generalized ordering

In Figure 4, "input ICONreq" is before "out IDISind", "in ICONresp", and "out ICONind". "out ICONind" is before "in ICONresp". "out IDISind" is unordered with "out ICONind" and "in ICONresp".

A MSC instance can be referred by another MSC. This technique is called **instance decomposition**. It is used to determine the transition between different entities of different levels of abstraction. The referred MSC may have explicit name or take the same name as the instance. In both MSC/PR and MSC/GR, the keyword **decomposed** is used.

The **inline expression** describes alternative ways for event execution in the MSC. It is used to hold different situation in the presentation of the system. There are five inline express, **alt, opt, par, loop, exc.**

The **alt inline expression** means there are two set events and only one set is executed. In such case, MSC has common part of events and separate part belongs to each case. The keyword **alt** is used in MSC/PR. See the example in Figure 5 that shows the special situation where "user A" is busy.




```
msc Reply_A_Busy;
instance User_A;
 condition Status_Check_A shared
all;
 out Facility to inline Z via g1;
 In Facility_2 from network;
 condition User_A_Busy shared all
endinstance;
instance Network;
 condition Status_Check_A
    shared all;
 alt begin Z ;
   gate g1 out Facility to lost
    external in Facility from User_A;
   timeout T;
 alt;
   gate g1 out Facility to Network;
   in Facility from env via g1;
    reset T;
 alt end;
out Facility_2 to User_A;
out Suspend to User_B;
condition User_A_Busy shared all
endinstance;
instance User_B;
 condition Status_Check_A
    shared all;
 In Suspend from network;
 condition User_A_Busy shared all
endinstance;
endmsc
```

Figure 5, An inline alt example in MSC/GR and MSC/PR

In Figure 5, in alternative 1, network is waiting for a message from user A but the message is lost. Then timer T is expired. In alternative 2, network received the busy message and reset time T. The gate "g1" is the inline gate used to define the connection point for the inline expression to outside. There are also timeout, send message to lost and gate interface in the Figure 5.

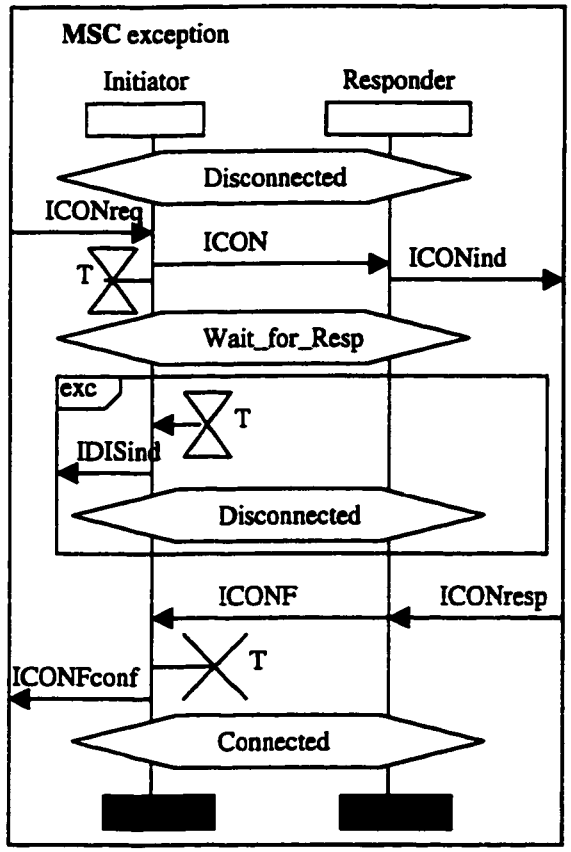
The **opt inline expression** means the part of event of the system is optional. That means the part of system may never happen. It is same as an **alt inline expression** where the second operand is the empty MSC. The keyword **opt** is used in MSC/PR.

The **par inline expression** means that all events within the parallel sections are executed. The only restriction is that the event order within each section is preserved. The keyword **par** is used in MSC/PR.

The **loop inline expression** is the set of events will be executed at least some times (low boundary) and at most some times (upper boundary). The loop may execute infinite time if the upper boundary is infinitive. It may also not be executed at all if the lower boundary is greater than upper boundary. The keyword **loop** is used in MSC/PR.

The **exc inline expression** means a compact way to describe exceptional cases in a MSC. The mean of the operator is that either the events inside the exc inline expression are executed and then the MSC is finished, or the events following the exc inline expression are executed. It likes the **alt inline expression**, which the second part is the entire part of MSC after the **exc inline expression**. The keyword **exc** is used in MSC/PR. There is an example in Figure 6.

Figure 6 shows that the system connection is either failure or success. The connection is failed if the response is not coming within time expiration, then the system will remain disconnected. The connection is success if the response is coming in time, then system is connected.




```
msc exception;
Initiator: instance;
Responder: instance;
all : condition disconnected;
Initiator: in ICONreq from env;
           out ICON to Responder;
           set T;
Responder: in ICON from Initiator;
           out ICONind to env;
all:  condition Wait_for_Resp;
      exc begin;
  Initiator: timeout T;
             out IDISind to env;
   all :     condition Disconnected;
      exc end;
 Responder: in ICONresp from env;
            out ICONF to Initiator;
 Initiator: in ICONF from Responder;
            reset T;
            out ICONFconf to env;
 all : condition Connected;
 Responder: endinstance;
 Initiator: endinstance;
endmsc;
```

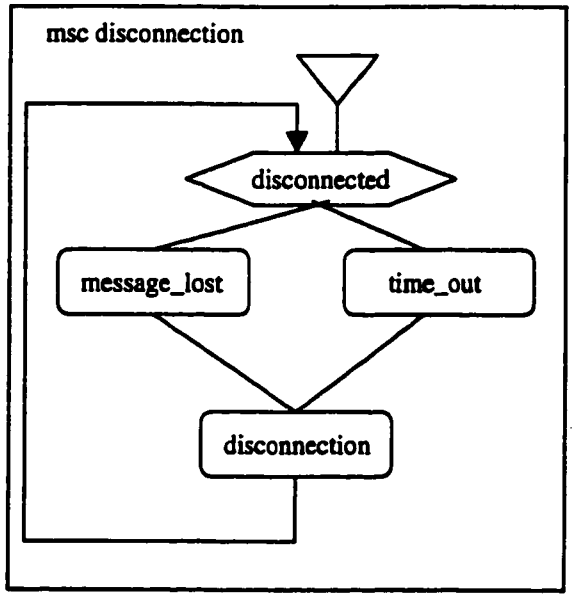
Figure 6 An inline exception example in MSC/GR and MSC/PR

The **MSC reference** is used to refer other MSC in the same document. It may also have the mapping from the current MSC element to the referred MSC element. Such element can be messages, instances, gates, and MSCs. MSC reference is done by a point to the reference text in MSC/GR and by the keyword **reference** in MSC/PR.

MSC'96 defines all above structure concepts. In addition to that, it also defines **high level MSC** (HMSC). The elements of a **high level MSC** can be MSC (basic MSC or high level MSC), **conditions, MSC reference**, and connecting point of MSCs. The whole system is divided into objects and each object is a MSC. HMSC explains how the whole system is constructed and how is the overall control. HMSC can also define the alternative execution path or a parallel subsystem. The subsystem may also be described by HMSC.

Often the word MSC refers to high level MSC.

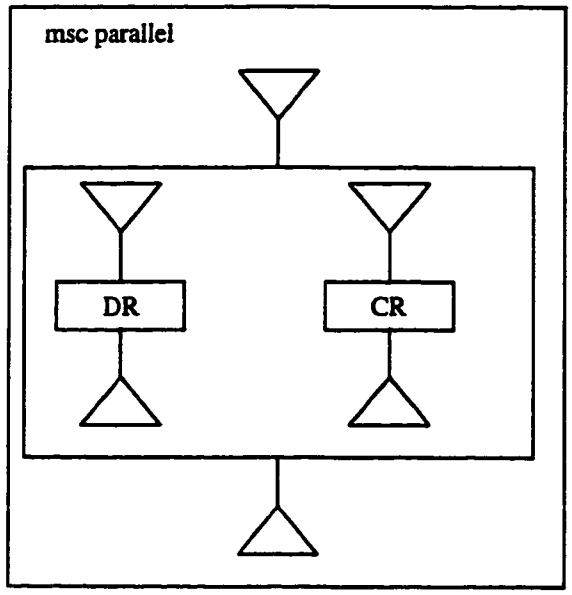
Figure 7 shows a system started from disconnected state and tries to connect. Due to either request message is lost or time is out, the system goes back to disconnected state. MSC "message_lost" is that system receives a connection message from environment and lost inside system. MSC "time_out" is that the request is send out to environment after getting connection message, but time is out before getting response from environment. MSC "disconnection" is that a disconnect indicator is sent to environment. Those basic MSC is not drawn in the figure 7.




```
msc disconnection;
expr L1:
  L1: condition disconnected
     seq (L2 alt L3);
  L2: message_lost seq (L4);
  L3 : time_out seq (L4);
  L4: disconenction seq (L1);
endmsc;
```

Figure 7 High level MSC disconnection

Figure 8 shows parallel composition. The system receives a connection request from "Initiator" and a disconnection request from the 'Responder' at a same time. Two requests are parallel. The basic MSCs CR and DR are not showed in the figure.




```
msc parallel;
expr L1:
  L1: expr L2;
      L2 : CR seq (L3);
      L3 : end;
      endexpr;
 par
      expr L4;
       L4 : DR seq (L5);
       L5 : end;
      endexpr;
 seq (L6);
 L6 : end;
endmsc;
```

Figure 8 High level parallel MSC

2.3 Deviation from standard MSC/PR

In this section, some detail of MSC/PR, which is not mentioned in last two sections, but they are related to the project will be discussed. The concrete textual grammar of MSC is listed in Appendix A.

The grammar defines **MSC document**. A MSC document contains one or several MSCs. The MSC inside the same **document** is visible to others. A MSC can refer to another MSC in the same **document**. Usually the high level MSC is put with its basic MSC element in the same document. Only one MSC **document** is allowed for one MSC textual file [2]. The MSC document defined here is different from the text file generated by ObjectGEODE [15].

MSC uses Backus-Naur-Form (BNF) in its grammar. The name of a MSC object is take wider ranger characters in the Z.120. Those characters include notional like '#', or '{'. The grammar used has minor variations from the standard, in that names have a more restrict syntax. Our syntax is defined here:

<alphanumeric> ::= <letter> | < decimal digit>
<full stop> ::= .
<underline> ::= _
<word> ::= { <alphanumeric> | < full stop> } * <alphanumeric> { <alphanumeric> | <full stop> } *
<name> ::= <word> { <underline> <word> }*

MSC has three types of comments. First one is started with "/*" and end with "*/", this one is supported by this project. The second one is started with keyword **text**, but this one only appears in a fix place in the grammar. According to the grammar, it can only appear in the body of basic MSC. The third is started with keyword **comment**. Z.120 attaches it with the end symbol, ';'. This make it can appear in the end of event statement. In this project, I changed to not attaching the end symbol. If the keyword **comment** is found, all the following characters in the same line will be ignored.

In Z.120, the <identifier> ::= [<< <text> >>] <name>. In the project, only take the name, as <identifier> ::= <name>.

There are two types of representations, instance-oriented and event-oriented. The MSC/PRs in the Figure 1 to Figure 5 are instance-oriented. The MSC/PR in the Figure 6 is event-oriented. Event-oriented textual representation is new to MSC and more readable than instance-representation. Both representations can be used, but the semantic of mix usage is not very clear [2,7]. User should not mix them in an MSC. Also an instance must declared first before it has event. It can not have event after it is ended.

The gates in the MSC can have order with **other gates**. A **default order out gate** is before one event. The **default order in gate** is before another **gate**. The display rules are very complicated. Also there are not enough examples can be found. Therefore this project only supports to parser the orderable gate, not to display it.

The grammar of inline expression of MSC makes it possible to have new instance declared inside the **inline expression**, and also a nesting **inline expression**. User can

declare a new set of **instances** inside **inline expression** and have all events belonged to the new **instance**. However it is not what the **inline expression** means and makes cause confusing. Since the structure of **MSC reference** and **high level MSC** are powerful, I assume no one uses pervious method. No nesting **inline expression** is supported although maximum five nesting **inline expressions** are supported in the parser part. The events inside the **inline expression** belong to the **instances** which own the inline expression.

MSC reference can have very powerful combination according to the grammar, but the usage is not clear [7].

2.4 Microsoft Visual C++ and MFC

Microsoft Visual C++ (Visual C++) is a software package based on PC. Visual C++ can be used to compile and build a program, which is written in C/C++. It has a graphic interface for the user to edit their programs, list class hierarchy tree [10]. Visual C++ with its sophisticated application framework, is for professional programmers [8]. The build-in class libraries are tools for user to create applications for windows. The basic library is Microsoft Foundation Class [10].

The window base program processes user input via message from the operation system. MFC simplify programming by hiding the main function and structuring the message-handler process [10]. The **AppWizard** in MFC is a code generator that creates a working skeleton of a windows application [8]. The base class in MFC is **CObject**. The general-purpose classes are derived from **CObject** [10]. Those classes are file manager,

data structure collections, template based classes. **CString** class, **CStringList** class, and template **CList** class are used as basic data structures in this project.

CObject is the principal base class of MFC. It serves as the root both for library classes and the classes defined by user. It supports serialization, run-time class information, object diagnostic output and compatibility with collection classes [10].

CString represents a variable length string. It is the replacement of C strings and the associated standard C library. It has a constructor which user can pass C style string. It overloads binary operators like compare two CStrings. This class is used to hold the name in the MSC/PR. **CString** can be used as const char* in C.

CStringList is a list class , which is a doubly link list for store CStrings. It has following main functionality: adding an element in the head or tail of the list, peeking the list head and tail, removing an element or all elements from the list, accessing the element of the list, inserting an element into the list at any position, iterating through the list, and finding an element.

CList , CList< TYPE, ARG_TYPE >, is a template version of the list class. It allows user to store any type of data. **TYPE** is type of object stored in the list. **ATG_TYPET** is the type used to reference objects stored in the list. It supports ordered lists of non-unique objects. Access the objects can be done by sequentially or by value.

CPoint represents a two-dimensional point with x, y coordinates.

The Graphic Device Interface (GDI) refers to the graphic output functions to windows. GDI separates the window program from physical devices such as screen. All GDI functions appear as the member function of **CDC** class. User can do all drawing through the member functions of a **CDC** object. **CDC** class provides member functions

for device-context operations, working with drawing tools, type-safe graphics device interface (GDI) object selection, and working with colors and palettes. It also provides member functions for getting and setting drawing attributes, mapping, working with the view port, working with the window extent, converting coordinates, working with regions, clipping, drawing lines, and drawing simple shapes, ellipses, and polygons. **CDC** member functions are also provided for drawing text, working with fonts, using printer escapes, scrolling, etc.

In the **AppWizard**, **CDocument** class and **CView** class are basic classes to display the draw.

A document represents the unit of data that the user typically stores in. The **CDocument** class provides the basic functionality for user-defined document classes.

CDocument class supports standard operations such as creating a document, loading it, and saving it. The framework manipulates documents using the interface defined by **CDocument.**

An application can support more than one type of document. Each type of document has an associated **document** template; the document template specifies what resources are used for that type of document. Each document contains a pointer to its associated **CDocTemplate** object.

Application programs interact with a document through the **CView** object(s) associated with it. A **view** renders an image of the document in a frame window and interprets user input as operations on the document. A document can have multiple **views** associated with it. When the user opens a window on a document, the framework creates

a **view** and attaches it to the document. The document template specifies what type of **view** and frame windows are used to display each type of **document.**

Documents are part of the framework's standard command routing and consequently receive commands from standard user-interface. A **document** receives commands forwarded by the active **view.** If the **document** doesn't handle a given command, it forwards the command to the **document** template that manages it.

When a **document's** data is modified, each of its **views** must reflect those modifications. **CDocument** has the **UpdateAllViews** member function to notify the **views** of such changes.

A **view** is attached to a **document** and acts as an intermediary between the document and the user: the **view** renders an image of the **document** on the screen , printer, etc. The **CView** class provides the basic functionality for user-defined **view** classes.

A **view** is a child of a frame window. More than one **views** can share a frame window. A **CDocTemplate** object establishes the relationships between a **view** class, a frame **window** class, and a **document** class. When the user opens a new window, the framework constructs a new **view** and attaches it to the **document.**

A **view** can be attached to only one **document,** but a **document** can have multiple **views** attached to it at once. User application can support different types of **views** for a given **document** type. For example, a word-processing program might provide both a complete text **view** of a **document** and an outline **view** that shows only the section headings. These different types of **views** can be placed in separate frame windows or in separate panes of a single frame window.

A **view** may be responsible for handling several different types of input. A **view** receives commands forwarded by its frame window. If the view does not handle a given command, it forwards the command to its associated **document** through a message map.

The **view** is responsible for displaying and modifying the **document**'s data but not for storing it. The **document** provides the **view** with the necessary details about its data. A **view** access the **document**'s data members directly or by member functions in the **document** class for the **view** class to call.

When a **document**'s data changes, the **view** responsible for the changes typically calls the **CDocument::UpdateAllViews** function for the document, which notifies all the other **views**.

Chapter 3 The Software Tool

This section describes the overview of the software I developed. The software input is a text file, which contains the textual MSC. The software tool has three functions. The first one is parsing a MSC/PR text according to the grammar of MSC'96. The second is building a set of objects of the classes in the MSC/PR. And the other is displaying the shape of those classes in a window.

The requirements of this project are to parse the text format MSC, detect syntax or semantics errors, create the objects to represent the MSC concepts like instance, message and action, and to represent their relationships, and to draw those objects in the window.

3.1 Overall design

The software is divided into three subsystems : parser, MSC structure, and visual classes. Each subsystem represents one of the three functions. The system is not a three layers system. Actually it is like three set of functions or classes dependence on the language. Both C and C++ are used. The overview of the tool is in Figure 9.

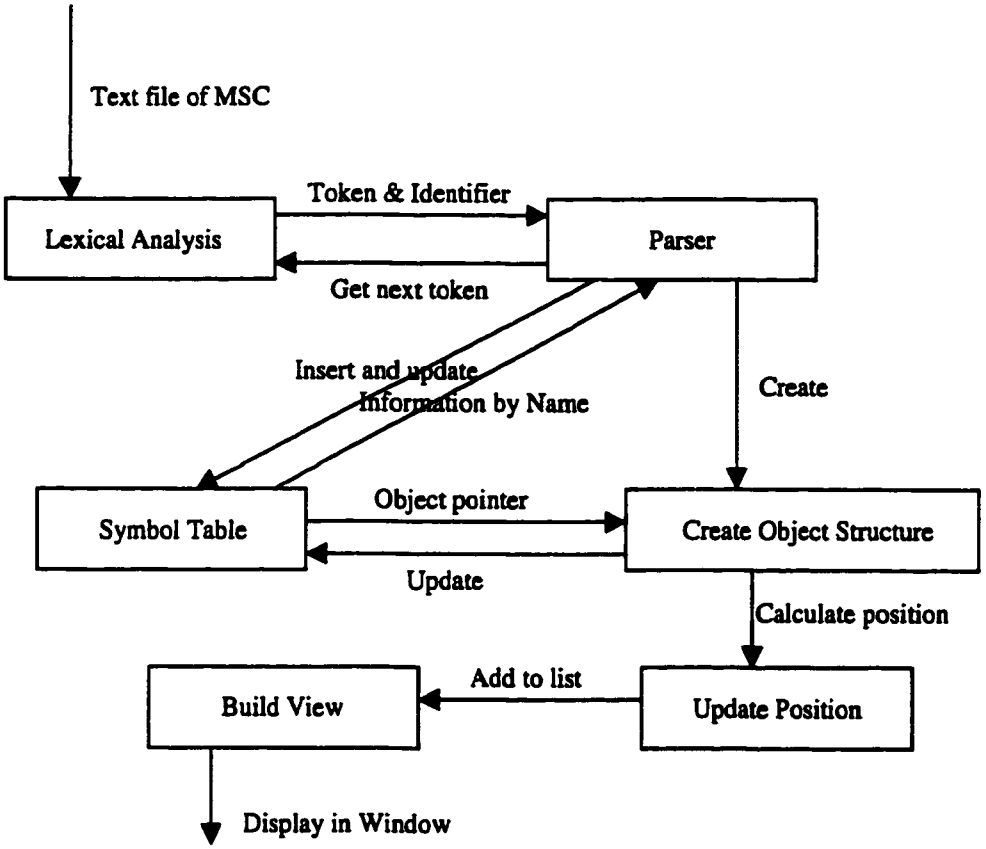


Figure 9 : The overview of the tool to display a textual MSC

The parser subsystem has a set of C functions for the parser. The parser has three subsets of functions. The first subset functions are used to read string from the text file to the buffers, delete white space, and then get the next token. See appendix B for the list of Token. The second subset functions are parser functions. They uses the token information and production rule of the grammar to check the syntax. Some functions are recursive. The third subset functions are used to build symbol table to check semantics. The symbol table is also used to build the classes. The symbol table is a class. Two symbol tables object pointers are used. One has the name of each MSC and pointer to it. The other one has all the important element of one MSC.

MSC structure subsystem is a collection of classes. It defines the classes and their relationships. It looks like a relational database with entities. The classes are in same level except inline loop class that is a child class of inline class. An object of the class, which represents the element of MSC, represents an object of a MSC. For example : an object of **instance** class is created for an instance of a MSC. A MSC has a correspond MSC object. Using the construct functions and other element functions, the objects of the classes are built during the parsing. The whole classes relationship diagram looks like a tree. The **MSC document** is the root node; Basic MSC or HMSC is its child. Class **instance** is a child of basic MSC, and so on. All the objects can be reached through the object of **MSC document** object. This object has pointers that pointed to the MSC or HMSC in the **MSC document.**

The parser functions are the draw force to invoke other functions. The objects of the classes are built during parsing the text file. After a MSC is parsed, all the objects of that MSC are known. The symbol table is used to update some objects.

The draw part is done by calculating the position of each object in the display window. Assign the sharp class to each object. The shape class is assigned to a list in the AppWizard **view** document. After the **document** is built. the view class will display those object in the windows. All are done after the parser is finished.

Some restrictions, such as the length of a name, are applied in this project. The whole software is not case sensitivity that means user used lower case is same as the upper case.

3.2 Details of parsing the MSC/PR

The parser sub-system has three sets of functions as mentioned in previous sections. The first set is used for lexical analysis. The second set is used for parser analysis. The last one is a C like class used for symbol analysis. The parser is base on top_down parser method. The input file is only read once to retrieve.

In the parser subsystem, we use some restrictions due to the limitation of the program. The maximum length of a name, L_IDENTIFIER, is 32.

In the lexical analysis, two buffers, each size is 256, are used. Using two buffers is for the lookahead technique. At the beginning of parsing, two blocks of characters are read into the buffer. The function MSC_lx_getchar() is used to get a character; After return the last character in the current buffer, it will switch buffer by pointer switch, and load a new buffer by calling buffer function. Function MSC_lx_lookahead() is used to returning next character to read as a peek. Function MSC_lx_skip_wsp() is used to skip all white space, like space, tab, or comments. MSC_lx_get_token() is to get next token. MSC_lx_get_token() calls MSC_lx_skip_wsp() to skip white space, then gets next character and decides what to do according a global table. The table, which is used for each ASCII character, is an array of structure. The structure contains the function pointer and a token code associated with the character. There are two kind function pointers, which point to function MSC_lx_letter() and MSC_lx_just_return(). Those functions will return the token. MSC_lx_get_token() passes the return token to the calling function. If the character is one of the characters made **word**, MSC_lx_letter() is called. The **word** definition is given in section 2.3. In this function, it calls another function to get a stream of characters, which make a word. Then if it is underlined next, call the function to get

another word. Repeat until the string passes the limit of a name or to a character that is not in the word definition. Then this **name** string is compared with the keywords, and returns either the token of the keyword or a token of identifier to indicate the string is a name. The string is stored for further usage if it is an identifier. MSC_lx_just_return() is just return the token assigned in the table. For most character, the token returned is an error token to indicate unexpected character, for example: $, is found. The other is return the token value, for example: char ';'. The char ';' is a terminal symbol. Each MSC statement is ended with ';', like in C/C++ language [9,12].

The main assumptions in the lexical analysis is that the input file is a non-empty text file.

The parser functions are built according to product rule. The parser uses the recursive descent method [11]. The name of the function starts with MSC_ps_. For example: rule 11 <msc inst interface> ::= **inst** <instance list> <end>. The function to parse it is: MSC_ps_msc_inst_interface() is like

```
MSC_ps_msc_inst_interface(){
        get token inst;
        MSC_ps_instance_list() ;
        MSC_ps_end();
}.
```

Another example is for rule 12, <instance list> ::= <instance name> [:<instance kind>][,<instance list>]. The function is like:

```
MSC_ps_instance_list() {
        if ( token == name ) {
                get name;
                if ( token == ':' )
                        MSC_ps_instance_kind() ;
                if (token == ',' )
                        MSC_ps_instance_list();
        }
```

}

A global variable is used to record the current token. The parser of high level MSC is straightforward. But the parser of basic MSC is difficult and will be discussed in the following parts.

The problem we got is that MSC'96 is not a LL1 grammar [11]. Sometimes the second token is needed to decide which rule should be used. In the event-oriented representation, a name can be the name of **instance** or the name of event according to the product rule 22 to 30 (in appendix A). The MSC/PR in figure 3 can be rewritten as:

```
msc TSD;
inst Initiator, Responder;
Initiator : instance ;
          in ICONreq from env;
          out ICON to Responder before label1;
Responder : instance;
              label1 in ICON from Initiator;
Initiator :  out IDISind to env;
            endinstance;
Responder :  in ICONresp from env;
              endinstance;
endmsc;
```

In this example, the identifier Responder is a name of **instance**, which is the start of <event definition>. The identifier label1 is the name of event, which is start of <orderable event> . Only knowing next token is a name, it is not enough to decide which product rule to be used. A structure, similar to the stack, is used to store token. The push function stores a token to the stack. The retrieve function either returns the store token or gets a new one if the stack is empty. This structure is also used later in the inline expression since **inline expression** needs two tokens to know its end.

Another problem is that the <instance name list> can only have one **instance**. By the rule 22 to 30 and the rule 60 to 65, both following statements are correct.

instance_name : condition condition_name shared; <--- <instance event>

instance_name : condition condition_name; <--- <multi instance event>

But the following statements are wrong:

instance_name : condition condition_name shared; <--- <instance event>
alt begin inline_name ; <--- <multi instance event>

instance_name : condition condition_name; <--- <multi instance event>
out message_1 to env ; <--- <instance event>

since they mix the product rule of <instance event list> and <multi instance event list>. In such case, using which product rule can not be decided until the keyword **shared** is found or not found. Then the parser knows the rule for next event statement. A set of functions and a local static variable are used to deal with this problem. The variable is set to be single instance statement at the beginning of rule 22. Then it changes the value if multi instance event statement is found. The above problem is also the reason why the keyword **shared** should be in the statement even a condition is only for an instance.

Some product rules share one function, like rule 76 and rule 82. This is because the above reason and they are similar. In the grammar is the in rule 81 to 86. <inline expr> calls back to <msc body>. The parser is push the local variable, which is used to distinguish **multi-instance** event list and single instance event list, to another stack and pop out later.

In symbol analysis, a class, MSC_table, is used. This table is a hash table using double hash functions. The node of the table is a structure. The structure has name of the element (used as a key), name type(the name is event name, ..), status(like declared,

defined), and a general pointer pointed to the object(like to the instance). The class has following public element functions.

- search_table() : search table by the name.
- insert_table() : insert a element into the table. If the element is already in table, either ignore the insert or print a error message. The message name can be duplicated. The other names are not.
- update_table() : either updates the status or the object pointer by key name.
- get_ptr() : return the object pointer.
- get_status() : return the status by the name or the position.
- update_event_link(): update the pointer of orderable event. Since the after event is only known after all MSC is parsed.

A global table is created for the **MSC document**. It contains the name of the MSCs in the **document**. For each MSC, a local MSC_table object is created. This table contains all the name of **instance, message** name, event name, etc. defined in the MSC.

In MSC'96, an **instance** is declared by an **instance** head statement and ended by an **instance** end statement. Each **instance** must have a header and an end statement. An **instance** can have event only after it is declared. The other **instances** can have **message** statement related to it. An **instance** can not have any event after it ends. If there is a **instance interface** in the MSC header, it must contains the same **instances** as specified in the **msc body**.

A function check_inst_in_table() is used when a **instance** name is found. It will insert into the table if not exist in the table, or check the status in the table. Another

function is used to check if the **instance** declared in the head statement is match to the one in interface.

3.3 Details of the object structure for MSC

Building the represent classes is done in the parser function. An **instance** object is created as soon as it is insert into the local table since all its events have to be attached to the event list. It also makes it possible for other object to point to it. In the basic MSC, only **instance** name, **inline expression** name, and **MSC reference** name may appear before its declaration. In such case, the name is in the **message** address. Also the **instance** name may be in the shared list of shared event before it is declared. The type of an **instance** in the interface, if has one, must be same as its head statement. The **instance** object is updated when the **instance** is declared.

The **message** object is created right after it is first declared. A **message** from **instance** to **instance** must appear in both **instances** event lists. So it is checked in the second time declaration. Other objects are created in their declaration function and built across several parser functions.

3.4 Details of drawing MSC

Each class is associated a sharp. For example: the sharp of a message is an arrow. After the parser is done, all the objects of the MSC are known. Currently we use the fixed window size in this project. In the basic MSC, the number of **instances** and the window's horizontal size decides for the horizontal distance between **instances**. The vertical size is close to the window's vertical size. The number of event is counted for each **instance**. After the largest number of events is known. The largest number and the

window's vertical size decide for the vertical distance between events of an **instance**. The event horizontal position is aligned to the axis of the **instance**. For the event across event, the vertical position is adjusted. The draw sharp of each object is added to the view list once.

The document list is used. It is a template list that can store an arbitrary collection of all sharps in any sequence. The draw class defined in the project has the capability to draw itself. Then draw in window is accomplished by stepping through the sharp list.

3.5 Major Classes in the tool

In this sector, we will discuss the major classes used in represent the MSC. There are two set of classes. One set is used to represent the elements of MSC. The other one is used to represent the sharp of the elements.

All classes are derived classes from **msc_element** class. The class **msc_element** itself is a derived class from **CObject**.

3.5.1 Classes used to represent MSC element

The major classes to represent the elements of MSC are:

- **msc_element** : Base class to represent an element in MSC.
- **msc_document** : represents the whole document of MSCs.
- **msg_seq_chart** : represents the basic Message Sequence Chart.
- **HMSC_expression** : represents the high level MSC.
- **instance** : represents the instance in a basic MSC.
- **msc_gate** : represents the gate in a basic MSC.

- **order_inst_event** : represents the orderable event of an instance in basic MSC.
- **message** : represents the message in a basic MSC.
- **msc_condition** : represents the condition in MSC.
- **msc_timer** : represents the timer in basic MSC.

Class **msc_inline, msc_reference, simple_event, msc_action,** and **create_instance_class** are used to represent other elements. The relationships between classes are showed in the figure 10 and explained after the figure.

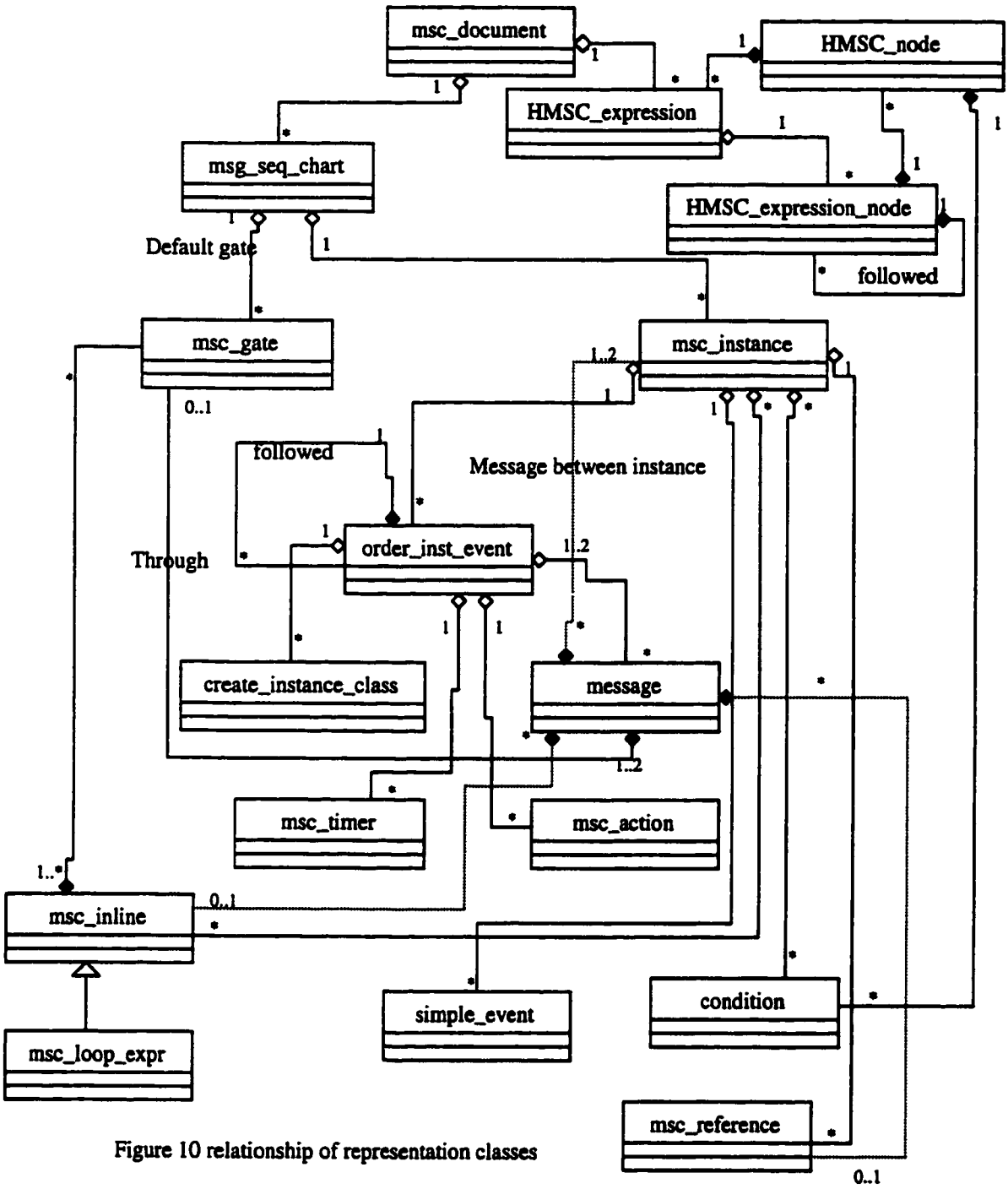


Figure 10 relationship of representation classes

The msc_element class contains same important attributes for name, sharp, and position. Those attributes are the common parts of all MSC elements. Another good point to have this base class is that an instance can have a list of **msc_element**. The pointer of the **instance** msc_element list can be assign to different element, like **condition** or

orderable event. All the classes are "declare dynamic" [10]. By that, the program calls run-time lib to get run-time information about an object's class. Some virtual functions are defined in **msc_element** and its deriving classes.

The **msc_document** class has two lists of pointers. One is a pointer list of basic MSC. This list has pointers pointed to all the basic MSCs in the document. The other list is a list of pointers of high level MSC. This list has pointers pointed to all the high level MSCs. If viewing the relation of elements of MSC as, then **msc_document** is the root of the tree. A basic MSC or a high level MSC is belongs to one **MSC document**. There is only one **msc_document** object for one MSC'96/PR file.

To make things straightforward, I am going to discuss **HMSC_expression** after I finish all elements of basic MSC.

The **msg_seq_chart** (basic MSC) class has two pointer lists. One is **instance** pointer list and the other one is a **gate** pointer list. Each **instance** of the MSC has a corresponding pointer in the **instance** pointer list. An **instance** is visible inside MSC. The **gate** pointer list records all the **default in gates** and **default out gates** of the MSC. **The default order in gate** and **default order out gate** are not represented in this tool since I can not understand them clearly. The class **msc_gate** will be discussed in the end of basic MSC classes.

The instance class contains the **instance kind** (process) information defined in the **instance head statement. Instance** has an important list, inst_event_list. This list is a **msc_element** pointer list. Since all the MSC elements are the derived class of **msc_element**, the class of the objects pointed to can be determined in run time. With the advantage of virtual, even no class information is needed. When an **instance** has an

event, such as condition, the pointer to the event is added to the list. The pointed classes from instance are: **order_inst_event, msc_condition, msc_inline, msc_reference,** and **simple_event.** Some event, like **condition,** can belong to one or more **instances.** Some event, like the **order_inst_event,** is only belonged to one **instance.** An **instance** can have many events.

The **order_inst_event** is used to represent the orderable events. It has a pointer pointing to the event. The point is point to a **msc_element** object, which can be an object of class **message,** class **msc_timer,** class **msc_action,** or class **create_instance_class. Order_inst_event** also has a list of pointer pointed to the events ordered after it if there is one. For example: the statement

in ICONreq **from env before** label1, label2

in Figure 4 will created a **order_inst_event** object . This **order_inst_event** object has a pointer pointed to **message,** "in ICONreg from env". The object also has a pointer list that has two pointers pointed to two other objects of **order_inst_event.** These two objects have name label1 and label2.

Class **msc_timer** has attributes to record the name and duration of the timer and the action type(set, reset, timeout).

Class **msc_action** has a **CString** attribute to hold the action string.

Class **create_instance_class** has attributes of the created **instance** name, parameter list (**CString** list), and a pointer pointed to the **instance.**

Class **message** is another important class. It has a message type. This type records that the message is from what's kind of element to what's kind of element. For example: from **env** to **instance.** It has two **CString** objects to hold message from element name

and send to element name. It also has two pointers pointed to from/to elements. Message sent to (or received from) **environment** has one NULL pointers. A pointer is NULL indicates the side is unknown. Message has a **lost type** to indicate if the message is lost or not. A lost can be sender lost or receiver lost. Usually one pointer of the lost message will be NULL. But a lost message may still have both side information [2]. For example: sender lost may still have send name. Message has a parameter list. The pointers of message may point back to **instances**. Two instances may have two same message statements and will have same message object through different **order_inst_event.**

Class **condition** has a name list since its name can contains several strings. It has an **instance** name list , which has all **instances** that shares the condition. It also has an instance pointer list pointed to those **instances.**

The **simple_event** class is a mixed usage class. It is used to represent the event that doesn't need any other attribute, for example: **instance stop**. It current handler following events: **instance start, instance end, instance stop, coregion start, coregion end, inline separate line,** and **inline end line.** we will discuss inline staff later. The **coregion start**(or **coregion end**) tells when the enter (or leave) the **coregion.**

The **inline** class actually only contains the **inline** head information. we haven't built a real **inline** class. A real **inline** class must have a **instance** list and the list must be a subset of the **instances** that shared the **inline expression.** All the events inside the **inline expression** must be assigned to the **instance** in the **inline instance list** not to outside **instance.** It is also possible of nesting **inline expression.** That also make the draw function very complicated. It is left for further work. Now the **inline** class have two **gate** lists for the gates attach to the **inline expression.** Two lists are used to distinguish the

gates of different alternatives. An **instance** list is used to point to the instances that shared the **inline expression**. All the events inside the **inline expression** are assigned to the origin **instance**. The origin instance has the simple events to know when it goes into second alternative and when the **inline expression** is ended.

The **msc_loop_expr** is a derived class of **msc_inline**. It has addition loop boundary information.

The **msc_reference** class only records the reference string. Further work can be done to have a pointer list to MSCs.

The **msc_gate** class is used to represent the **default input gate, default output gate, inline input gate, inline out gate, actual input gate**, and **actual output gate**. The **orderable gate** is left for further work. The **msc_gate** has a type to indicate what kind of gate it is. It has one **message** pointer since a **gate** can be implicitly defined by the direction of the **message** through the gate and by the **message** name. A **gate** also can be explicitly defined by a name.

3.5.2 Classes used to represent high level MSC

Now we am going to discuss the classes represent high level MSC.

Class **HMSC_expression** has name list for its name. It has a **HMSC_expression_node** pointer list pointed to the node it has.

Class **HMSC_expression_node** has a pointer pointed to current node, and a list of pointers pointed to the node followed it.

Class **HMSC_node** has a type to indicate the node type, a name for the referred MSC or **condition**, or **msc_reference**. It also has a **HMSC_expression** pointer list to

point to the sub-expression belongs to the node. That sub-expression will be a parallel high level MSC expression.

The object model of Figure 3 is showed in Figure 11.

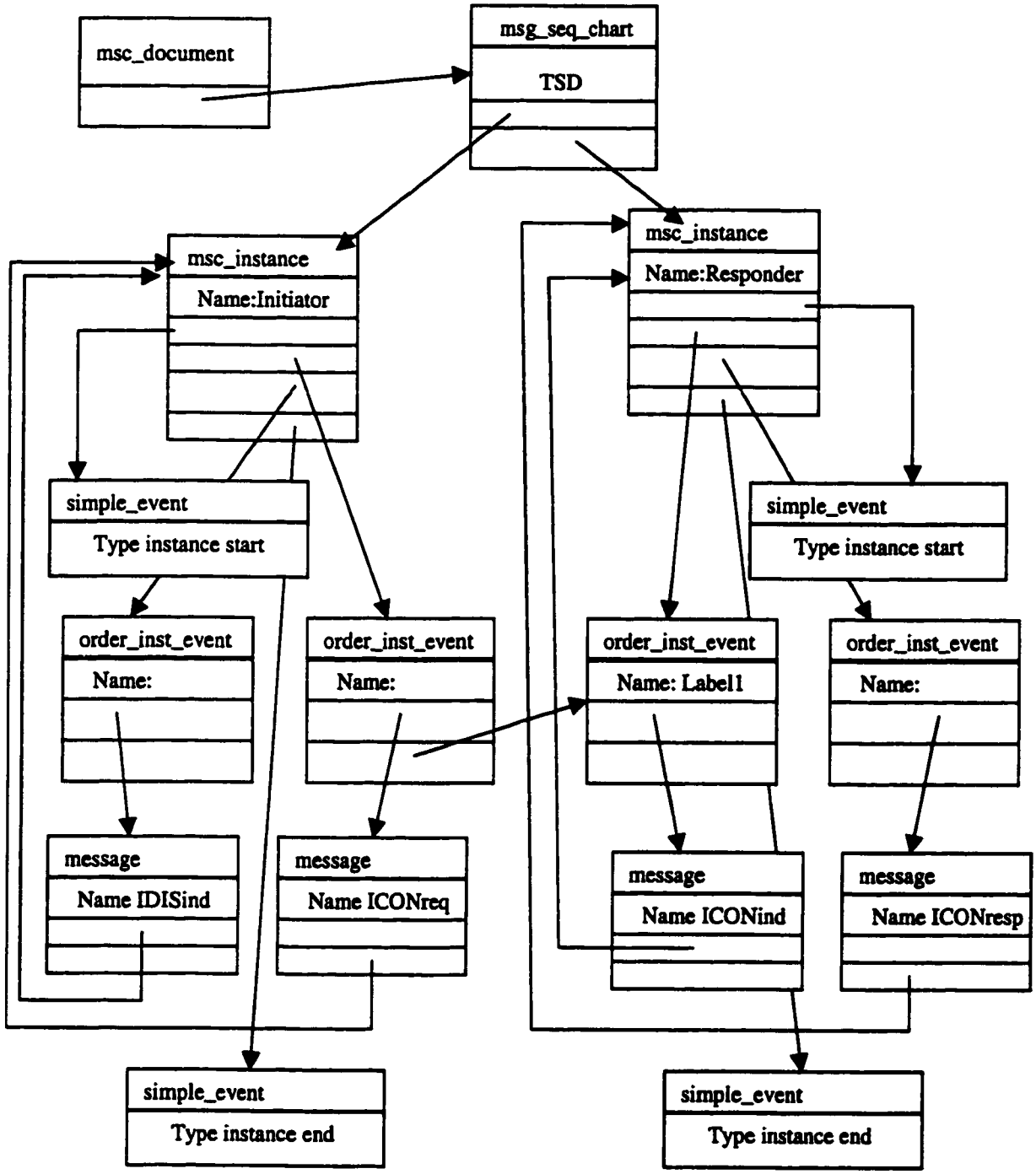


Figure 11 Object model for Figure 3

3.5.3. Classes represent the sharp of the MSC elements

The classes, which are used to represent the sharp of the MSC elements, are quite straightforward. Like the classes representing the MSC element, there is a base class, **CElement**.

CElement is a derived class from **CObject**. It has common attributes of the sharps used to display the element of MSC. Those attributes are : color (type **COLORREF**), EnclosingRectangle (**CRect**), Name (**CString**), and Name position point (**CPoint**). It has a virtual function draw, which take a CDC parameter.

Class **CLine** is used to draw a line. It needs the start and end point as its parameters.

Class **CDashLine** is used to draw a dash line. It also needs start and end point as parameters.

Class **CRectangle** is used to draw a rectangle. It uses an Enclosing Rectangle to transfer its parameter. So it also only needs two parameter Start point(left up point) and End point(right bottom point).

Class **CLineArrow** is used to draw an arrow. It uses a start and a end point. Current only vertical or horizontal arrow can be drawn.

Class **CDiamRect** is used to draw the Diamond Rectangle, which is used to present the condition. It is a collection of several line segments. It takes four parameter: one is used to pass a **View** point into the function, two is used to pass the drawing start and end point, another one is used to pass the visual unit **Vunit** .

Class **CTimeSetSymb** is used to draw the MSC timer set symbol . It is a collection of several line segments. It also takes four parameter: one is used to pass a

View point into the function, two are used to pass the drawing start and end point, another one is used to pass the **Vunit** .

Class **CTimeResetSymb** is similar to the class **CTimeSetSymb**, but it is used to present the MSC timer reset. It takes the same four parameters.

Class **CTimeOutSymb** is also similar to the class **CTimeSetSymb**, but it is used to present the MSC timer out. It takes the same four parameters.

Class **CCircle** is used to draw a circle. It is used to present the HMSC node, and used to draw the message found/lost symbol. It needs circle center point and the radium value as parameter.

Class **CMsgFoundSymb** is used to draw the MSC message found symbol. It is a collection of a line and a circle. It takes four parameter: one is used to pass a **View** point into the function, two is used to pass the drawing start and end point, another one is used to pass the **Vunit** which is used to determinate the radium of the circle.

Class **CMsgLostSymb** is similar to the class CMsgFoundSymb . It is used to present the MSC diagram of message lost. It also takes the same four parameters.

Class **CText** is used to present the text in the MSC diagram . It takes two parameter: one is a point that passes the start point of the text, another one is a **CString** which pass the text.

Chapter 4 Conclusion and Future Work

The main goal of this project is to display Message Sequence Charts. This project is the first step towards a more powerful tool that can display and edit MSC'96 model and be compatible with other existing MSC tools. Another goal is to learn software design and programming under the Windows environment.

The main steps in the tool of this project are parsing MSC/PR, creating the object structure to represent the MSC, and displaying under the Windows environment.

The grammar of MSC'96 is not easy to parse. The C language is used in this part because it is fast and efficient, and there are tools available for compilers [11].

The object structures to represent elements of MSC'96 are done in C++. It takes advantage of the object paradigm, which is supported by C++ [10]. The elements of MSC'96 have object characteristics, which makes it easy to convert MSC to an OO model.

The display part is done under Microsoft Windows because now PCs are widely used, and the windows program became more and more popular. Many software tools are built under Windows, and the Microsoft MFC library is an open library with many programming tools [10].

All the 22 examples listed in the end of the Z.120 standard are tested. The parser correctly identifies all errors in the examples. The object structure is correctly build for all examples. However the display part is not working in all cases now. It is due to the limitation of the time. Further work is needed in this area.

Through the work of the project, I gained a lot of valuable experiences about parsing complex languages, OO design, C++ and MFC. First of all, I now know the

importance of overall design and planning ahead. I learnt to make my design flexible for any future modification. Secondary, Programming under different environments is a quite valuable lesson. Now I clearly know the difference of the input/output method under UNIX and windows: the UNIX uses device driver to control I/O, while the window uses the message. Furthermore, I learnt the resource based program under windows with visual C++, i.e. we can store data in a resource file using a number of established format. Another thing I learnt in MFC is using the dynamic linked library. Now I knew how to use MFC run time type information and how to link the document to its view. In addition, in this project I mixed the C structured design and C++ object oriented design. I used almost all the C++ OO design features: class hierarchies, template, access control, operator overloading, friend class member, polymorphism, etc. All these are very good experiences for me.

The tool I built is far from perfect. Many improvements need to be done, say as the following.

Create a class to fully encapsulate MSC inline. This class may be similar to msg_seq_chart class. Also the class for MSC reference should be able to handle all kinds of references.

The display should be improved to allow screen scrolling, multiple display windows, and to link related diagrams.

The whole software can be improved to be clear and reliable.

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Appendix A The Grammar of MSC'96

In the grammar of MSC'96, a terminal symbol is either indicated by not inside < > or it is one of <name> and <character string>. Keywords are in bold. A non-terminal symbol is indicated inside < and >. A production is given for each non-terminal symbol.

The symbol 'I' is used for alternative productions; '{' and '}' means the element is group together; * is used to indicate the group is for optional and can be further repeated any number of times; + is used to indicate the group must appear once and can be further repeated any number of times; [and] means optional. A underlined part stresses a semantic aspect of the symbol. For example: <msc name> means the name is a MSC name. It is same as <name>.

The Backus-Naur-Form of the textual token is not include in this appendix. The important tokens are:

<alphanumeric> ::= <letter> I < decimal digit>
<full stop> ::= .
<underline> ::= _
<word> ::= { <alphanumeric> I < full stop> } * <alphanumeric> { <alphanumeric> I <full stop> } *
<name> ::= <word> { <underline> <word> }*

Also <character string> means a string inside two apostrophes. For example, 'Take action' .

The start symbol is <msc document>.Rule 1 and 6 are the rules that deviate from the standard for this project.

1 <end> ::= ;
2 <msc document> ::= <msc document head> <msc document body>
3 <msc document head> ::= <document head>
4 <msc document body> ::= {<message sequence chart>}*

5 <document head> ::= **mscdocument** <msc document name> [**related to** <sdl reference>] <end>
6 <sdl reference> ::= <sdl document identifier>
7 <identifier> ::= <name>

8 <message sequence chart> ::= **msc** <msc head> { <msc body> I **expr** <msc expression> } **endmsc** <end>
9 <msc head> ::= <msc name> <end> [<msc interface>]
10 <msc interface> ::= [<msc inst interface>] [<msc gate interface>]

11 <msc inst interface> ::= **inst** <instance list> <end>
12 <instance list> ::= <instance name> [:<instance kind>][,<instance list>]
13 <instance kind>::= [<kind denominator>]<identifier>
14 <kind denominator>::= **system** | **block** | **process** | **service** | <name>

15 <msc gate interface> ::= <msc gate def>*
16 <msc gate def> ::= gate {<msg gate> | <order gate>} <end>
17 <msg gate> ::= <def in gate> | <def out gate>
18 <order gate> ::= <def order in gate> | < def order out gate>

19 <msc body> ::= <msc statement>*
20 <msc statement> ::= <test definition> |
<event definition> |
<old instance head statement> <instance event list>
21 <test definition>::= **text** <character string> <end>
22 <event definition>::= <instance name> : <instance event list> |
<instance name list> : <multi instance event list>
23 <instance event list> ::= {<instance event> <end>}+
24 <instance event> ::= <orderable event> | <non-orderable event>
25 <orderable event>::=
[<event name>]
{<message event>|<incomplete message event> |<create> |<timer statement> |<action>}
[**before** <event name list>]
26 <event name list>::= {<event name> |<gate name>} [,<event name list>]
27 <non-orderable event> ::= <coregion> | <shared condition> | <shared msc reference> |
<shared inline expr> | <instance head statement> | <instance end statement>|
<stop>
28 < instance name list> ::= <instance name> {,<instance name>}* | **all**
29 <multi instance event list> ::= {<multi instance event> <end>}+
30 <multi instance event>::=<condition>| <msc reference> | <inline expr>

31 <old instance head statement> ::=
instance <instance name> [[:] <instance kind>][<decomposition>]<end>

32 <instance head statement> ::= **instance** [<instance kind>][<decomposition>]
33 <instance end statement> ::= **endinstance**

34 <message event> ::= <message output>|<message input>
35 <message output> ::= **out** <msg identification> **to** <input address>
36 <message input> ::= **in** <msg identification> **from** <output address>
37 <incomplete message event> ::= < incomplete message output>|< incomplete message input>
38 <incomplete message output> ::= **out** <msg identification> **to lost** <input address>
39 <incomplete message input> ::= **in** <msg identification> **from found**<output address>
40 <msg identification> ::= <message name> [,<message instance name>][(<parameter list>)]
41 <parameter list>::= <parameter name> [,<parameter list>]
42 <output address> ::= <instance name> | {**env** | <reference identification>}[**via** <gate name>]
43 <reference identification> ::= **reference** <msc reference identification> |
inline <inline expr identification>
44 <input address> ::= <instance name> | {**env** | <reference identification>}[**via** <gate name>]

45 <actual out gate> ::= [<gate name>] **out** <msg identification> **to** <input dest>
46 <actual in gate> ::= [<gate name>] **in** <msg identification> **from** <output dest>
47 <input dest> ::=**lost** [<input address>] | <input address>
48 <output dest> ::= **found** [<output address>] | <output address>
49 <def in gate> ::= [<gate name>] **out** <msg identification> **to** <input dest>
50 <def out gate> ::= ::= [<gate name>] **in** <msg identification> **from** <output dest>

51 <actual order out gate> ::= <gate name> **before** <order dest>
52 <order dest> ::= <event name> | {**env** | <reference identification>} **via** <gate name>
53 <actual order in gate> ::= <gate name>
54 <def order in gate> ::= <gate name> **before** <order dest>
55 <def order out gate> ::= <gate name>
56 <inline out gate> ::= <def out gate>
[**external out** <msg identification> **to** <input dest>]
57 <inline in gate> ::= <def in gate>
[**external** in <msg identification> **from** <output dest>]
58 <inline order out gate> ::= <gate name> [**external before** <order dest>]
59 <inline order in gate> ::= <gate name> **before** <order dest> [**external**]

60 <shared condition> ::= <condition identification> <shared>
61 <condition identification> ::= **condition** <condition name list>
62 <condition name list> ::= <condition name> {,<condition name>}*
63 <shared> ::= **shared** {[<shared instance list>] | **all**}
64 <shared instance list>::= <instance name> [,<shared instance list>]
65 <condition> ::= <condition identification>

66 <timer statement> ::= <set> | <reset> | <timeout>
67 <set> ::= **set** <timer name> [, <timer instance name>] [<duration name>]
68 <reset> ::= **reset** <timer name> [, <timer instance name>]
69 <timeout> ::= **timeout** <timer name> [, <timer instance name>]

70 <action> ::= **action** <action character string>
71 <create> ::= **create** <instance name> [(<parameter list>)]
72 <stop> ::= **stop**
73 <coregion> ::= **concurrent** <end> <coevent>* **endconcurrent**
74 <coevent> ::= <orderable event> <end>

75 <shared inline expr> ::= <shared loop expr> | <shared opt expr> | <shared alt expr> |
<shared par expr> | <shared exc expr>

76 <shared loop expr> ::= **loop** [<loop boundary>] **begin** <inline expr identification>] <shared> <end>
[<inline gate interface>] <instance event list>
loop end
77 <shared opt expr> ::= **opt begin** <inline expr identification>] <shared> <end>
[<inline gate interface>] <instance event list>
opt end
78 <shared exc expr> ::= **exc begin** <inline expr identification>] <shared> <end>
[<inline gate interface>] <instance event list>
exc end
79 <shared alt expr> ::= **alt begin** <inline expr identification>] <shared> <end>
[<inline gate interface>] <instance event list>
{ **alt** <end> [<inline gate interface>] <instance event list> }*
alt end
80 <shared par expr> ::= **par begin** <inline expr identification>] <shared> <end>
[<inline gate interface>] <instance event list>
{ **par** <end> [<inline gate interface>] <instance event list> }*
par end
81 <inline expr> ::= <loop expr> | <opt expr> | < alt expr> | <par expr> | <exc expr>
82 <loop expr> ::= **loop** [<loop boundary>] **begin** <inline expr identification>] <end>
[<inline gate interface>] <msc body>
loop end
83 <opt expr> ::= **opt begin** <inline expr identification>] <end>
[<inline gate interface>] <msc body>

opt end

84 <exc expr> ::= **exc begin** <inline expr identification>] <end>
[<inline gate interface>] <msc body>
exc end

85 <alt expr> ::= **alt begin** <inline expr identification>] <end>
[<inline gate interface>] <msc body>
{ **alt** <end> [<inline gate interface>] <msc body> }*
alt end

86 <par expr> ::= **par begin** <inline expr identification>] <end>
[<inline gate interface>] <msc body>
{ **par** <end> [<inline gate interface>] <msc body> }*
par end

87 <loop boundary> ::= '<'<inf natural> [,<inf natural>] '>'

88 <inf natural> ::= **inf** | <natural name>+

89 < inline expr identification> ::= <inline expr name>

90 <inline gate interface> ::= {**gate** <inline gate> <end>}+

91 <inline gate> ::= <inline out gate> | <inline in gate> |
<inline order out gate> | <inline order in gate>

92 <shared msc reference> ::= **reference** [<msc reference identification> :] <msc ref expr>
<shared> [<reference gate interface>]

93 <msc reference> ::= **reference** [<msc reference identification> :] <msc ref expr>
[<reference gate interface>]

94 < msc reference identification> ::= <msc reference name>

95 <msc ref expr> ::= <msc ref par expr> {**alt** <msc ref par expr>}*

96 <msc par expr> ::= <msc ref seq expr> {**par** <msc seq par expr>}*

97 <msc seq expr> ::= <msc ref exc expr> {**seq** <msc exc par expr>}*

98 <msc ref exc expr> ::= [**exc**] <msc ref opt expr>

99 <msc ref opt expr> ::= [**opt**] <msc ref loop expr>

100 <msc ref loop expr> ::= [**loop**] [<loop boundary>]
{**empty** |<msc name> [<parameter substitution>] | (<msc ref expr>) }

101 <parameter substitution> ::= **subst** <substitution list>

102 <substitution list> ::= <substitution> [,<substitution list>]

103 <substitution> ::= <replace message> | <replace instance> | <replace msc>

104 <replace message> ::= [**msg**] <message name> **by** <message name>

105 <replace instance> ::= [**inst**] <instance name> **by** <instance name>

106 <replace msc> ::= [**msc**] { **empty** | <msc name> } **by** { **empty** | <msc name> }

107 <reference gate interface> ::= {<end> **gate** <ref gate>}*

108 <ref gate> ::= <actual out gate> | <actual in gate> | <actual order out gate> | <actual order in gate>

109 <decomposed> ::= **decomposed** [<substructure reference>]

110 <substructure reference> ::= **as** <message sequence chart name>

111 <msc expression> ::= <start> <node expression>*

112 <start> ::= <label name> {**alt** <label name>}* <end>

113 <node expression> ::=
<label name> : {<node> **seq** (<label name> {**alt** <label name>}*) | **end**} <end>

114 <node> ::= (<msc ref expr>)
| **empty** | <msc name>
| <par expression>
| **condition** <condition name list>
| **connect**

115 <par expression> ::= **expr** <msc expression> **endexpr** {**par expr** <msc expression> **endexpr** }*

Appendix B Tokens

Token symbol	Means
T_NONE	Not token, error char
T_L_B	Left '('
T_R_B	Right')'
T_COMMA	','
T_COLON	':'
T_S_COMMA	';'
T_APOSTROPHE	''
T_LT	'<'
T_GT	'>'
T_IDENT	identifier
T_ACTION	keyword **action**
T_ALL	keyword **all**
T_ALT	keyword **alt**
T_AS	keyword **as**
T_BEFORE	keyword **before**
T_BEGIN	keyword **begin**
T_BLOCK	keyword **block**
T_BY	keyword **by**
T_COMMENT	keyword **comment**
T_CONCURRENT	keyword **concurrent**
T_CONDITION	keyword **condition**
T_CONNECT	keyword **connect**
T_CREATE	keyword **create**
T_DECOMPOSED	keyword **decomposed**
T_EMPTY	keyword **empty**
T_END	keyword **end**
T_ENDCONCURRENT	keyword **endconcurrent**
T_ENDEXPR	keyword **endexpr**
T_ENDINSTANCE	keyword **endinstance**
T_ENDMSC	keyword **endmsc**
T_ENV	keyword **env**
T_EXC	keyword **exc**
T_EXPR	keyword **expr**
T_EXTERNAL	keyword **external**
T_FOUND	keyword **found**
T_FROM	keyword **from**
T_GATE	keyword **gate**
T_IN	keyword **in**
T_INF	keyword **inf**
T_INLINE	keyword **inline**
T_INST	keyword **inst**

T_INSTANCE	keyword	**instance**
T_LOOP	keyword	**loop**
T_LOST	keyword	**lost**
T_MSC	keyword	**msc**
T_MSCDOCUMENT	keyword	**mscdocument**
T_MSG	keyword	**msg**
T_OPT	keyword	**opt**
T_ORDER	keyword	**order**
T_OUT	keyword	**out**
T_PAR	keyword	**par**
T_PROCESS	keyword	**process**
T_REFERENCE	keyword	**reference**
T_RELATED	keyword	**related**
T_RESET	keyword	**reset**
T_SEQ	keyword	**seq**
T_SERVICE	keyword	**service**
T_SET	keyword	**set**
T_SHARED	keyword	**shared**
T_STOP	keyword	**stop**
T_SUBST	keyword	**subst**
T_SYSTEM	keyword	**system**
T_TEXT	keyword	**text**
T_TIMEOUT	keyword	**timeout**
T_TO	keyword	**to**
T_VIA	keyword	**via**

Appendix C List of C Functions

MSC_RETURN_TYPE MSC_lx_init_1(FILE *p_input_file)
    // initialize the read file buffer and global variables

static int MSC_lx_read_bf(FILE *p_input_file, char *p_buffer)
    // read character string from file to the buffer

static MSC_RETURN_TYPE MSC_init_buffer(FILE * p_input_file)
    // Read the buffer at the initial time

char MSC_lx_getchar(FILE *p_input_file)
    // gets next character from buffer. return null if it is end of file

char MSC_lx_lookahead()
    // Function looks next available char

void MSC_lx_get_string(FILE *p_input_file, char *p_out_string)
    // gets the string up to end of line or end of file.

static void MSC_init_alphanumeric()
    // initialize alphanumeric char array used to check a char is alphanumeric or not

int MSC_Is_Alphanumeric(char p_ch)
    // check a char is alphanumeric or not

static void MSC_lx_get_alphanumeric_string(FILE *p_input_file, char *p_char, int * p_length)
    // get alphanumeric char string followed by p_char from the buffer

static MSC_RETURN_TYPE MSC_lx_get_word(FILE *p_input_file, char *p_string, int *p_length)
    // get the pointer and length of a word string start with p_char.

MSC_RETURN_TYPE MSC_lx_get_name(FILE *p_input_file, char *p_string)
    // gets a name string. Name string is defined by MSC

void test_main()
    // test main function to run the tool

static int MSC_lx_init(FILE *p_input_file)
    // Overall initialize function

FILE *MSC_get_file_ptr()

// Return current file pointer

char *MSC_get_name()
// Return current name string of an identifier

static void MSC_lx_skip_wsp(FILE *p_input_file, char p_ch)
// skip white space

MSC_token_td MSC_lx_get_token()
// get next token

static MSC_token_td MSC_lx_letter(FILE *p_input_file)
// lexical function used to analysis alphanumeric char start string
// It is call MSC_lx_get_name to get a name

static int MSC_compare_key_word(const void *p_keyv_ptr, const void *p_table_entry_ptr)
// compare a name string against a key enter in the word table. Like comp function

static MSC_token_td MSC_lx_check_key(char *p_string)
// check a string is keyword or not.

static MSC_token_td MSC_lx_number(FILE *p_input_file)
// lexical analyze for a string started with digit number. Not used in the project

static MSC_token_td MSC_lx_just_return(FILE *p_input_file)
// Return token assigned to the character

Please note : following parser function also build the represent classes object.

int MSC_ps_is_end_token(MSC_token_td p_token)
// check a token is <end>. This design is intent to add comment before the end

void MSC_ps_end()
// parser <end> rule 1

void MSC_ps_msc_document()
// parser grammar rule 2-7

void DrawSystem()
// start draw.

void SetViewPtr(CMscGraphicView* Vp)
// update view pointer of the object tree.

void MSC_ps_message_sequence_chart()

```
        // parser grammar rule 8

void MSC_ps_msc_head()
        // parser grammar rule 9, 10

void MSC_ps_msc_inst_interface()
        // parser grammar rule 11

void MSC_ps_instance_list()
        // parser grammar rule 12

void MSC_ps_instance_kind()
        // parser grammar rule 13, 14

void MSC_ps_msc_gate_interface()
        // parser grammar rule 15

void MSC_ps_msc_gate_def()
        // parser grammar rule 16-18 and part of 49, 50.and rule 55

void MSC_ps_def_in_gate()
        // parser grammar rule 49

void MSC_ps_def_out_gate()
        // parser grammar rule 50

void MSC_ps_def_order_in_gate()
        // parser grammar rule 54

void MSC_ps_msg_identification()
        // parser grammar rule 40 and 41

void MSC_ps_input_dest()
        // parser grammar rule 47

void MSC_ps_input_address()
        // parser grammar rule 44

void MSC_ps_output_dest()
        // parser grammar rule 48

void MSC_ps_output_address()
        //  parser grammar rule 42

void MSC_ps_input_output_address()
        // sub-function parser grammar rule 42, 44
```

void MSC_ps_order_dest()
// parser grammar rule 52

void MSC_ps_reference_identification()
// parser grammar rule 43

void MSC_ps_name_list(MSC_NAME_TYPE p_type, MSC_NAME_STATUS p_status)
//sub function to parser a name list, like <name> [,<name>]*

int MSC_ps_is_expr_token(MSC_token_td p_token)
// function to check if the token is a inline token

void MSC_ps_init_instance_no_type()
//initialize function to the stack of structure, which is used to check single or multi instances.

int MSC_ps_is_single_inst()
// Return true if the events belong to a single(one) instance

int MSC_ps_is_multi_inst()
// Return true if the events belong to multi (more than one) instances

void MSC_ps_reset_inst_no_type(MSC_INST_NO_TD p_inst_no_td)
// reset the stack

void MSC_ps_increase_inst_type_index()
// increase the stack pointer

void MSC_ps_decrease_inst_type_index()
// decrease the stack pointer .

void MSC_ps_put_back_token(MSC_token_td p_token)
// put the token into a temporary stack

void MSC_ps_get_store_token()
// get the token in the temporary storage or get one from the file

int MSC_is_any_store_token()
// return is there any stored token

int MSC_update_instances(MSC_NAME_STATUS p_status)
// update the instance status.

void MSC_add_all_instance_list(char *p_name)
// add an instance to all instance list

```
void MSC_ps_msc_body()
        // parser grammar rule 19

void MSC_ps_msc_statement()
        // parser grammar rule 20

void MSC_ps_text_definition()
        // parser grammar rule 21

void MSC_lx_get_text_string(char *p_text_string)
        // get text string

void MSC_ps_old_instance_head_statement()
        // parser grammar rule 31

void MSC_ps_event_definition()
        // parser grammar rule 22

void MSC_ps_decomposition(char *p_inst_name)
        // parser grammar rule 109 and 110

void MSC_ps_instance_event_list()
        // parser grammar rule 23

void MSC_ps_instance_event()
        // parser grammar rule 24

void MSC_ps_orderable_event(int p_inside_one_inst)
        // parser grammar rule 25

void MSC_ps_message_event()
        // parser grammar rule 34 and 37

void MSC_ps_message_output()
        // parser grammar rule 35 and 38

void MSC_ps_message_input()
        // parser grammar rule 36 and 39

void MSC_ps_create()
        // parser grammar rule 71

void MSC_ps_time_statement()
        // parser grammar rule 66 to 69
```

```
void MSC_ps_action()
        // parser grammar rule 71

void MSC_ps_multi_instance_event_list()
        // parser grammar rule 29

void MSC_ps_multi_instance_event()
        // parser grammar 30

void MSC_ps_non_orderable_event()
        // parser grammar 27

void MSC_ps_coregion()
        //      parser grammar 73 NS 74

void MSC_ps_condition()
        //   parser grammar 65

void MSC_ps_msc_reference()
        // parser grammar 92 , 93 AND 94

void MSC_ps_msc_ref_expr()
        //      parser grammar 95

void MSC_ps_msc_ref_par_expr()
        //      parser grammar 96

void MSC_ps_msc_ref_seq_expr()
        //      parser grammar 97

void MSC_ps_msc_ref_exc_expr()
        //      parser grammar 98

void MSC_ps_msc_ref_opt_expr()
        //      parser grammar 99

void MSC_ps_msc_ref_loop_expr()
        //      parser grammar 100

void MSC_ps_parameter_substitution()
        //      parser grammar 101

void MSC_ps_substitution_list()
        //      parser grammar 102

void MSC_ps_substitution()
        //      parser grammar 103, 104, 105, and 106
```

```
void MSC_ps_ref_gate()
        //      parser grammar 107 and 108

void MSC_ps_actual_out_gate()
        //      parser grammar 45

void MSC_ps_actual_in_gate()
        //      parser grammar 46

void MSC_ps_actual_order_out_gate()
        //      parser grammar 51

void MSC_ps_inline_expr()
        //      parser grammar 75 and 81

void MSC_ps_loop_expr()
        //      parser grammar 76 and 82

void MSC_ps_opt_expr()
        //      parser grammar 77 and 83

void MSC_ps_exc_expr()
        //      parser grammar 78 and 84

void MSC_ps_alt_expr()
        //      parser grammar 79 and 85

void MSC_ps_par_expr()
        //      parser grammar 80 and 86

void MSC_ps_inline_expr_term(MSC_token_td p_token, MSC_INLINE_TYPE p_type,
char * p_function_name )
        // sub function parser common part of each inline expression and grammar 89

void MSC_ps_inline_gate_interface()
        //      parser grammar 90

void MSC_ps_inline_gate_interface_term()
        //      parser grammar 91

void MSC_ps_inline_out_gate()
        //      parser grammar 56

void MSC_ps_inline_in_gate()
        //      parser grammar 57
```

```
void MSC_ps_inline_order_out_gate()
        //      parser grammar 58

void MSC_ps_inline_order_in_gate()
        //      parser grammar 59

void MSC_ps_instance_head_statement()
        //      parser grammar 32

void MSC_ps_instance_end_statement()
        //      parser grammar 33

void MSC_ps_stop()
        //      parser grammar 72

void MSC_ps_shared(SHARED_TYPE p_shared_type)
        //      parser grammar 63 and 64

void MSC_ps_loop_boundary(MSC_NAME_TYPE p_type)
        //      parser grammar 87 and 88

void MSC_call_msc_body()
        //      function pushes other variables before call msc_bosy

void MSC_ps_msc_expression(HMSC_expression *p_hmsc)
        //      parser grammar 111

void MSC_ps_start(HMSC_expression *p_hmsc)
        //      parser grammar 112

void MSC_ps_node_expression(HMSC_expression *p_hmsc)
        //      parser grammar 113

void MSC_ps_node(HMSC_expression_node *p_expr_node)
        //      parser grammar 114

void MSC_ps_par_expression(HMSC_node *p_node)
        //      parser grammar 115
```

Following is the utility functions, which are used to build the objects

```
void MSC_print_token(MSC_token_td p_token)
        //      print token name by token number

int MSC_ps_insert_message()
```

```
        // Create and insert a message object into local table

message * MSC_ps_create_message()
        // create message object

void MSC_ps_insert_order_event(char *p_name, order_inst_event *p_order_event)
        // insert the order inst event into the local table

int check_inst_in_table(char *p_name, MSC_NAME_STATUS p_status)
        // check the instance status by using local table

void MSC_ps_update_inst_in_table(char *p_inst_name, instance *p_instance)
        // update the instance definition in the local table

void MSC_ps_update_instances_event(MSC_element *p_event)
        // Add event to each instance on the current instance list

Instance_List *MSC_ps_get_inst_ptr_list(CStringList& p_name_list)
        // return an instance pointer list by a name list
```

Appendix D Class Dictionary

1 Class MSC_eleement

```
typedef enum {LINE,RECTANGLE} CElement_shape;

class MSC_element : public CObject
{
        DECLARE_DYNAMIC(MSC_element)
public:
        virtual void draw(void) const{};
        virtual void print_item(void) const{} ;
        virtual void update_DrNo(int DrawNo){};
        virtual void update_pos(MSC_element *PriorElementPtr,
                                long Hunit,long Vunit){};
   virtual void update_ViewPtr(CMscGraphicView* ptr){m_ViewPtr = ptr;};

        MSC_element() ;
        MSC_element(char *p_string) ;
        inline int operator == (const MSC_element &e) const {
              return ( element_name == e.element_name)  ;
           }

protected:
        CString element_name ;
        CElement_shape m_shape;
public:
        int m_DrwOdrNo;
        CMscGraphicView* m_ViewPtr;
        CPoint m_AxisStart;
        CPoint m_AxisEnd;
} ;

typedef CList<MSC_element*, MSC_element*> MSC_Element_List;
```

2 Class msc_document

```
class msc_document : public MSC_element
{
        DECLARE_DYNAMIC(msc_document)

public:
        virtual void draw(void) const;
        virtual void print_item(void) const;
```

```
        virtual void update_DrNo(int DrawNo);
        virtual void update_pos(MSC_element *PriorElementPtr,long Hunit,long Vunit);
        virtual void update_ViewPtr(CMscGraphicView* ptr);

        msc_document(char *p_name) : MSC_element(p_name) {m_DrwOdrNo = 0;} ;
        void add_basic_msc(msg_seq_chart *p_msc) {
                        msc_seq_chart_list.AddTail(p_msc); } ;

        void add_high_msc(HMSC_expression *p_hmsc) {
                        HMSC_expression_list.AddTail(p_hmsc) ; } ;

private :
   Msg_Seq_Chart_List  msc_seq_chart_list;
   HMSC_Expression_List HMSC_expression_list ;
} ;
```

3 Class msg_seq_chart

```
class msg_seq_chart : public MSC_element
{
        DECLARE_DYNAMIC(msg_seq_chart)

public:
        virtual void draw(void) const;
        virtual void print_item(void) const;
        virtual void update_DrNo(int DrawNo);
        virtual void update_pos(MSC_element *PriorElementPtr,long Hunit,long Vunit);
        virtual void update_ViewPtr(CMscGraphicView* ptr);

        msg_seq_chart() : MSC_element(), instance_list()  {m_DrwOdrNo = 0;} ;

        msg_seq_chart(char * p_msq_seq_chart_name)
                : MSC_element(p_msq_seq_chart_name), instance_list()
                {m_DrwOdrNo = 0;} ;

        void add_instance(instance *p_instance) ;
        void add_gate(msc_gate *p_gate) ;

        friend class MSC_table ;
        friend  class CMscGraphicView;

private:
        Instance_List instance_list ;
        Gate_List def_gate_list;
} ;
```

```
typedef CList<msg_seq_chart*, msg_seq_chart*> Msg_Seq_Chart_List;
```

4 Class instance

```
class instance : public MSC_element
{
        DECLARE_DYNAMIC(instance)
public:
        virtual void draw(void) const;
        virtual void print_item(void) const;
        virtual void update_pos(MSC_element *PriorElementPtr,long Hunit,long Vunit);
        virtual void update_DrNo(int DrawNo);
        virtual void update_ViewPtr(CMscGraphicView* ptr);

        instance() : MSC_element(), kind_denominator(), kind_name(),
                  inst_event_list(), decomposion_name()
                { decomposion_ptr = NULL ;   m_DrwOdrNo =0;    } ;

        instance(char * p_inst_name) : MSC_element(p_inst_name), kind_denominator(),
                kind_name(),  inst_event_list(), decomposion_name()
                { decomposion_ptr = NULL ;  m_DrwOdrNo = 0;} ;

        int  update_instance(const instance &p_inst) ;

        void update_kind_denominator(char *p_kind_denominator) ;
        void update_dmom_name(char *p_dmom_name) ;
        void update_decom_name(char *p_name) { decomposion_name = p_name ; } ;

        void add_inst_event(MSC_element *p_event) ;
        void print_name() { printf("inst name is %s \n", element_name); };

        friend MSC_table ;
        friend message ;

private:
        CString kind_denominator ;
        CString kind_name ;
        MSC_Element_List inst_event_list ; // point to all event belonged to this instance
        msg_seq_chart  *decomposion_ptr ;
        CString decomposion_name;

        CPoint m_InstStart1;
        CPoint m_InstStart2;

        CPoint m_InstEnd1;
        CPoint m_InstEnd2
```

```
};

typedef CList<instance*, instance*> Instance_List;
```

5 Class order_inst_event

```
typedef order_inst_event*  Order_Inst_Event_Ptr ;
typedef CList<Order_Inst_Event_Ptr, Order_Inst_Event_Ptr> Order_Inst_Event_List;

class order_inst_event : public MSC_element
{
  DECLARE_DYNAMIC(order_inst_event)

public:
        virtual void draw(void) const;
        virtual void print_item(void) const;
        virtual void update_DrNo(int DrawNo);
        virtual void update_pos(MSC_element *PriorElementPtr,long Hunit,long Vunit);
        virtual void update_ViewPtr(CMscGraphicView* ptr);

        order_inst_event();
        order_inst_event(char *p_name, MSC_element *p_element);

        void add_after_event_name(CStringList *p_event_name_list) ;

        friend MSC_table ;

private:
        MSC_element *event;
        CStringList after_event_name;
        Order_Inst_Event_List after_event;
};
```

6 Class Timer

```
typedef enum {
        UNKNOWN_TIME ,
        SET_TIME ,
        RESET,
        TIME_OUT
} ACT_TIMER_TYPE ;

class msc_timer : public MSC_element
{
  DECLARE_DYNAMIC(msc_timer)
```

```
        msc_timer() ;
        msc_timer(char* p_timer, ACT_TIMER_TYPE p_type) ;
        msc_timer(char* p_timer, char* p_duration);

public:
        virtual void draw(void) const;
        virtual void print_item(void) const;
        virtual void update_DrNo(int DrawNo);
        virtual void update_pos(MSC_element *PriorElementPtr,long Hunit,long Vunit);
        virtual void update_ViewPtr(CMscGraphicView* ptr){m_ViewPtr = ptr;};

private:
        ACT_TIMER_TYPE act_type ;
        CString duration ;

        CPoint m_TimerStartPoint;
        CPoint m_TimerEndPoint;
} ;
```

7 Class Create Instance

```
class create_instance_class : public MSC_element
{
  DECLARE_DYNAMIC(create_instance_class)

public:
        virtual void draw(void) const;
        virtual void print_item(void) const;
        virtual void update_DrNo(int DrawNo){};
        virtual void update_pos(MSC_element *PriorElementPtr,
                        long Hunit,long Vunit){};

        create_instance_class() ;
        create_instance_class(char *p_name);
        create_instance_class(char *p_name, CStringList *p_para_list);
        void update_inst_ptr(instance *p_inst) ;
private:
        CString created_instance_name ;
        instance *created_instance ;
        CStringList inst_parameter_list ;
} ;
```

8 Class msc_action

```
class msc_action : public MSC_element
{
  DECLARE_DYNAMIC(msc_action)

public:
        virtual void draw(void) const;
        virtual void print_item(void) const;
        virtual void update_DrNo(int DrawNo){};
        virtual void update_pos(MSC_element *PriorElementPtr,
                long Hunit, long Vunit){};


        msc_action(char *p_name) : MSC_element(), action_string(p_name) {} ;
private:
  CString action_string;
};
```

9 Class message

```
typedef enum {
  UNKNOWN_DIRECTION = 0 ,
        INST_TO_INST ,
        ENV_TO_INST ,
        INST_TO_ENV ,
        REF_TO_INST,
        INST_TO_REF,
        INLINE_TO_INST,
        INST_TO_INLINE,
        TO_GATE,
        FROM_GATE
} MESSAGE_TYPE ;

typedef enum {
        NOT_LOST ,
        INPUT_LOST,
        OUTPUT_LOST
} MESSAGE_LOST_TYPE ;


class message : public MSC_element
{
  DECLARE_DYNAMIC(message)

public:
        virtual void draw(void) const;
        virtual void print_item(void) const;
```

```
        virtual void update_DrNo(int DrawNo);
        virtual void update_pos(MSC_element *PriorElementPtr,long Hunit,long Vunit);
        virtual void update_ViewPtr(CMscGraphicView* ptr){m_ViewPtr = ptr;};

        message();
        message(char *p_string, MESSAGE_TYPE p_type ,
                MESSAGE_LOST_TYPE p_lost_type , char *p_from_name,
                    char *p_to_name, char *p_gate) ;

        void add_from_element(MSC_element *p_from_inst)
                { from_inst = p_from_inst; } ;
        void add_to_element(MSC_element *p_to_inst)  { to_inst = p_to_inst; } ;

        friend int operator == (const message &msg1, const message &msg2 ) ;
        void  add_parameter(CStringList *p_list);

        friend MSC_table ;

public:
        MESSAGE_TYPE message_type ;
private:
        MSC_element *from_inst ;
        MSC_element *to_inst ;
        CString     from_name;
        CString     to_name;
        CStringList parameter_list ;
        MESSAGE_LOST_TYPE lost_type ;

        CString  via_gate_name ;
        msc_gate *via_gate ;

        CPoint m_MsgStart;
        CPoint m_MsgEnd;
};
```

10 Class simple_event

```
typedef enum {
        COREGION_START ,
        COREGION_END,
        INSTANCE_HEAD,
        INSTANCE_END,
        INSTANCE_STOP,
```

```
        INLINE_SEP_LINE,
        INLINE_END_LINE
} MSC_SIMPLE_EVENT_TYPE;

class simple_event : public MSC_element
{
  DECLARE_DYNAMIC(simple_event)

public:
        virtual void draw(void) const;
        virtual void print_item(void) const;
        virtual void update_DrNo(int DrawNo);
        virtual void update_pos(MSC_element *PriorElementPtr,long Hunit,long Vunit);
        virtual void update_ViewPtr(CMscGraphicView* ptr){m_ViewPtr = ptr;};

        simple_event(MSC_SIMPLE_EVENT_TYPE p_type) :
                MSC_element() { event_type = p_type ; } ;

private:
        MSC_SIMPLE_EVENT_TYPE  event_type ;
        CPoint m_SmpevtStart;
        CPoint m_SmpevtEnd;
};
```

11 Class condition

```
class MSC_table ;

class condition : public MSC_element
{
        DECLARE_DYNAMIC(condition)

public:
        virtual void draw(void) const;
        virtual void print_item(void) const;
        virtual void update_DrNo(int DrawNo);
        virtual void update_pos(MSC_element *PriorElementPtr,long Hunit,long Vunit);
        virtual void update_ViewPtr(CMscGraphicView* ptr);


        condition()     : MSC_element(), condition_name_list(),  shared_instance_list()
                {m_DrwOdrNo = 0;   m_OnceAccess = 0;  } ;

        condition(CStringList& p_condition_name_list) ;

        void add_shared_instance(Instance_List* p_shared_instance) ;
```

```
        friend MSC_table ;

private:
        CStringList condition_name_list;
        Instance_List shared_instance_list ;

        CPoint m_CdnStart;
        CPoint m_CdnEnd;
        int m_OnceAccess;
};
```

12 Class msc_inline

```
typedef enum {
        UNKNOWN_EXPR ,
        LOOP_EXPR ,
        OPT_EXPR,
        EXC_EXPR,
        ALT_EXPR,
        PAR_EXPR
} MSC_INLINE_TYPE ;

class msc_inline : public MSC_element
{
  DECLARE_DYNAMIC(msc_inline)

public:
        virtual void draw(void) const;
        virtual void print_item(void) const;
        virtual void update_DrNo(int DrawNo);
        virtual void update_pos(MSC_element *PriorElementPtr,long Hunit,long Vunit);
        virtual void update_ViewPtr(CMscGraphicView* ptr){m_ViewPtr = ptr;};

        msc_inline();

        msc_inline(char *p_string, MSC_INLINE_TYPE p_type) ;
        void  add_instacne(Instance_List *p_inst_list);
        void  add_inline_gate1(msc_gate *p_gate);
        void  add_inline_gate2(msc_gate *p_gate);

protected:
        MSC_INLINE_TYPE msc_inline_type ;
private:
        Gate_List msc_gate_list1 ;
        Gate_List msc_gate_list2 ;
        Instance_List instance_list ;
```

```
};
```

13 Class msc_loop_expr

```
class msc_loop_expr : public msc_inline
{
  DECLARE_DYNAMIC(msc_loop_expr)
public :
        msc_loop_expr() :  msc_inline(), lower_bound(), upper_bound()
                { msc_inline_type = LOOP_EXPR; } ; msc_loop_expr(char *p_string) :

        msc_inline(p_string, LOOP_EXPR), lower_bound(), upper_bound()
                {msc_inline_type = LOOP_EXPR; } ;

        void add_low_bound(char *p_bound) ;
        void add_up_bound(char *p_bound) ;
        void update_loop_name(char *p_string) { element_name = p_string ; } ;

        virtual void print_item(void) const;

private :
        CStringList lower_bound ;
        CStringList upper_bound ;
} ;
```

14 Class msc_reference

```
class msc_reference : public MSC_element
{
  DECLARE_DYNAMIC(msc_reference)

public:
        virtual void draw(void) const;
        virtual void print_item(void) const;
        virtual void update_DrNo(int DrawNo){};
        virtual void update_pos(MSC_element *PriorElementPtr, long Hunit,
                long Vunit){};

        msc_reference(char *p_name, char *p_string) ;

private:
        CString referr_item ;
};
```

15 Class msc_gate

```
typedef enum {
        UNKNOWN_GATE ,
        DEF_OUT_GATE,
        DEF_IN_GATE,
        ACTUAL_IN_GATE,
        ACTUAL_OUT_GATE,
        INLINE_IN_GATE,
        INLINE_OUT_GATE
} MSC_GATE_TYPE;

class msc_gate : public MSC_element
{
  DECLARE_DYNAMIC(msc_gate)

public:
        virtual void draw(void) const;
        virtual void print_item(void) const;
        virtual void update_DrNo(int DrawNo){};
        virtual void update_pos(MSC_element *PriorElementPtr, long Hunit,
                long Vunit){};
        msc_gate();
        msc_gate(char *p_name, MSC_GATE_TYPE p_type ) ;
        void update_related_msg(message *p_message) ;
        void update_extern_msg(message *p_message) ;

        friend message ;

public:
        MSC_GATE_TYPE msc_gate_type ;
private:
        message *related_msg ;
        message *extern_msg ;
};

typedef CList<msc_gate*, msc_gate*> Gate_List;
```

16 Class HMSC_node

```
typedef enum {
        REF_NODE,
        EMPTY_MSC,
        MSC_NODE,
        PAR_HMSC,
        CONDITION,
```

```
        CONNECT,
        END_NODE
} HMSC_NODE_TYPE;

class HMSC_expression;
typedef CList<HMSC_expression*, HMSC_expression*> HMSC_Expression_List ;

class HMSC_node : public MSC_element
{
        DECLARE_DYNAMIC(HMSC_node);

public:
        virtual void draw(void) const;
        virtual void print_item(void) const;

        HMSC_node(HMSC_NODE_TYPE p_type) ;
        HMSC_node(HMSC_NODE_TYPE p_type, char *p_string) ;
        HMSC_node(HMSC_NODE_TYPE p_type, CStringList *p_list) ;
        void add_par_hmsc(HMSC_expression *p_hmsc) {
                par_hmsc_list.AddTail(p_hmsc); } ;


private:
        HMSC_NODE_TYPE node_type ;
        CStringList name_list;
        HMSC_Expression_List par_hmsc_list ;

        int m_DrwOdrNo;
};
```

17 Class HMSC_expression_node

```
class HMSC_expression_node : public MSC_element
{
        DECLARE_DYNAMIC(HMSC_expression_node);

public:

        virtual void draw(void) const;
        virtual void print_item(void) const;

        HMSC_expression_node(char *p_name) ;
        void add_after_label(char *p_label) { after_label.AddTail(p_label); };
        void assign_node(HMSC_node *p_node) { hmsc_node = p_node; } ;
        void add_after_list(HMSC_expression_node* p_expression_node) ;
```

```
private:
        HMSC_node *hmsc_node ;
        CStringList after_label ;
        HMSC_Expression_Node_List *after_list
        int m_DrwOdrNo;
};

typedef CList<HMSC_expression_node*, HMSC_expression_node*>
        HMSC_Expression_Node_List;
```

18 Class HMSC_expression

```
class HMSC_expression : public MSC_element
{
  DECLARE_DYNAMIC(HMSC_expression);

public:
        virtual void draw(void) const;
        virtual void print_item(void) const;
        virtual void update_DrNo(int DrawNo){};
        virtual void update_pos(MSC_element *PriorElementPtr,long Hunit,
                long Vunit){};

        HMSC_expression() : MSC_element() , expression_label_list() , node_list() {} ;
        HMSC_expression(char *p_name)
                : MSC_element(p_name), expression_label_list() , node_list() {} ;

        void add_expression_label_list(char *) ;
        void add_node(HMSC_expression_node *) ;

private:
        CStringList expression_label_list;
        HMSC_Expression_Node_List node_list ;

};
```

Following Table is used to build symbol table.

19 Class MSC_table

```
typedef enum {
        UNKNOWN_NAME,
```

```
        MSC_NAME ,
        INST_NAME ,
        GATE_NAME,
        MSG_NAME,
        EVENT_NAME,
        PARA_NAME ,
        TIME_NAME,
        COND_NAME,
        REF_NAME,
        INLINE_NAME
} MSC_NAME_TYPE ;

typedef enum {
        UNKNOWN = 0 ,
        REFERRED,
        USED,
        DEFINED ,
        DECLARED,
        FINISHED
} MSC_NAME_STATUS ;

typedef struct {
 char name[L_IDENTIFIER+1] ;
 MSC_NAME_TYPE  type ;
 MSC_NAME_STATUS status ;
 MSC_element *object_ptr ;
} MSC_Element_Node  ;

class MSC_table {
public:
   MSC_table() ;
   ~MSC_table();
   int insert_table(char *p_name,MSC_NAME_TYPE p_type,
        MSC_NAME_STATUS p_status,  int p_ignore_duplicate ) ;
   int search_table(char *p_name);
   int update_table(char *p_name, MSC_element *p_ptr );
   int update_table(char *p_name, MSC_NAME_STATUS p_status) ;

   MSC_element *get_ptr(char *p_name);
   MSC_NAME_STATUS get_status(char *p_name) ;
   MSC_NAME_STATUS MSC_table::get_status(int p_position) ;
   MSC_NAME_TYPE get_type(int position) ;

  void update_event_link();
  void update_position();
   void print_table();
```

```
 private:
   int hashkey1(char *p_str , int M );
   int hashkey2(char *p_str ) ;
private:
   MSC_Element_Node element_table[TABLE_SIZE];
   CElement* m_pTempElement;
};
```