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泛用型軟體框架應用於手持系統之軟體架構設計及製作

A Generic Software Framework for the Software System Architecture Design and Implementation of Handset Devices

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摘　　要

在開發手機使用介面的傳統方法上，程式並不能立即反映出規格上的變動。一旦需求發生了變動，程式員就必須更改他們的程式。因此，發展使用介面將會耗費大量時間。

本校資工系的軟體工程實驗室，已經開發出一個軟體建構方法論[1]，並使用於發展手持系統的使用介面，能讓使用者介面快速的移植到新的平台。本研究與此方法論相配合，用來開發其軟體的架構，可以克服傳統方法所遇到的問題。

在各種使用者介面的設計以及軟體架構當中，存在著某種程度的相似性，本研究將這些相同的部分擷取出來，歸納成爲泛用型軟體框架(Generic Software Framework)。從這個泛用型軟體框架衍伸出來的軟體框架實例，應用在與視覺化的 UI 編輯器的配合，可以快速的開發出使用介面。

爲了驗證此開發方式的可行性，我們使用泛用型軟體框架，實作出一個軟體框架，來搭配視覺化的 UI 編輯器，並設計了軟體模擬器，來驗證所產生的使用者介面系統。

A Generic Software Framework for the Software System Architecture Design and Implementation of Handset Devices

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Abstract

The traditional approach to develop user interface for handset devices has limited flexibility on the UI requirement changes. Once the UI requirement changed, programmers have to change their handcrafted application once again. This change may occur repeatedly until the UI requirement under consideration is satisfied.

The Software Engineering Laboratory in NCTU has developed a Visual Requirement Authoring and Program Generation Methodology. This methodology helps programmers to develop the user interface for handset devices, and allows programmers to migrate their program to new platform quickly. Based on this methodology, we quest for a generic software framework to incorporate the proposed methodology for developing user interface to alleviate the problems mentioned above.

From our study, there are some similarities exist among user interface and software framework in different handset devices. In this research work, we propose a generic software framework for the system architecture design of handset devices. Specifically, the software framework generated based on the generic software framework will be much easier for maintenance and management compared with the traditional approach. In addition, the software framework that is instantiated from the generic software framework can be incorporated into the visual requirement authoring system for user interface development.

In this thesis study, we design and construct a simulator to demonstrate the applicability and usefulness of the software framework generated by the proposed generic software framework.

誌 謝

本論文承蒙指導教授陳登吉老師的耐心指導與教誨之下，得以順利完成，在此對老師致上謝意。老師認真辛勤的工作態度，對學生們來說，就是最好的身教。

同時要感謝在課業上給我協助的同學。建中、尚庭，我們三人分工合作，在相互勉勵之下，突破技術上的種種困難，得以完成這個研究。另外，家瑜、華坤同學以及博士生蔡明志老師，對我的鼓勵跟指教，以及實驗室的學弟學妹，在平時的幫忙，在此一併致謝。

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目錄

摘要 I

ABSTRACT II

誌謝 III

目錄 IV

表目錄 VI

CHAPTER 1 INTRODUCTION 1

1-1 MMI overview 1

1-2 Problem Statements & Motivation 1

1-3 Overview of this thesis 3

CHAPTER 2 SOFTWARE FRAMEWORK FOR HANDSET DEVICE AND RELATED WORK 4

2-1 Framework 4

2-2 The current software framework for handset devices 5
2-2-1 Man-Machine Interface (MMI) 6
2-2-2 Real-time operation system (RTOS) 6
2-2-3 GSM subsystem 7
2-2-4 Hardware devices and drivers 7
2-2-5 Signal 8

CHAPTER 3 THE VISUAL-BASED SOFTWARE CONSTRUCTION APPROACH AND GENERIC SOFTWARE FRAMEWORK 9

3-1 The visual-based authoring system 9

3-2 Methodology for using a software design framework to create software applications for handset devices 11

3-3 Architecture of the generic software framework 12

3-4 A comparison between software framework and generic software framework 15

CHAPTER 4 SOFTWARE FRAMEWORK GENERATION BASED ON GENERIC SOFTWARE FRAMEWORK 18

4-1 Software framework generation based on the generic software framework 18

4-2 Generic Kernel Interface (GKI) 19
4-2-1 Task 20
4-2-2 Mailbox 21

4-3 GSM task 22

4-4 Keypad ISR 23

4-5 The created software framework 23

CHAPTER 5 SYSTEM DESIGN AND IMPLEMENTATION 25

5-1 Design and Implementation of Generic Kernel Interface (GKI) 25
5-1-1 Signal 27
5-1-2 Task 30
5-1-3 Mailbox 34

5-2 UI task 36

5-3 MMI kernel task 38

5-4 GSM task 40

5-5 DSC task 42

5-6 Keypad ISR 43

5-7 Display API 44

CHAPTER 6 SIMULATION AND APPLICATION EXAMPLES 45

6-1 Introduction of the simulator 45

6-2 The design and implementation of the simulator 46
6-2-1 The software architecture of the simulator 46
6-2-2 The design and implementation of the simulator 47

6-3 Application examples 48
6-2-1 Making a phone call 49
6-2-2 Incoming call 50
6-2-3 Accept a call 51

CHAPTER 7 CONCLUSION AND FUTIRE WORKS 52

REFERENCES 54

表目錄

TABLE. 1 A COMPARISON BETWEEN SOFTWARE FRAMEWORK AND GENERIC SOFTWARE FRAMEWORK. 16

PROGRAM SAMPLE 1 20
PROGRAM SAMPLE 2 20
PROGRAM SAMPLE 3 26
PROGRAM SAMPLE 4 32
PROGRAM SAMPLE 5 33
PROGRAM SAMPLE 6 33
PROGRAM SAMPLE 7 33
PROGRAM SAMPLE 8 37
PROGRAM SAMPLE 9 37
PROGRAM SAMPLE 10 41
PROGRAM SAMPLE 11 42
PROGRAM SAMPLE 12 44

圖目錄

FIG. 1 FRAMEWORK OF UI DESIGN PATTERN GENERATOR AND 2
FIG. 2 THE CURRENT SOFTWARE FRAMEWORK FOR HANDSET DEVICES 5
FIG. 3 THE OF UI DESIGN PATTERN GENERATOR AND VISUAL BASED SOFTWARE CONSTRUCTION MODEL 9
FIG. 4 THE GENERIC SOFTWARE FRAMEWORK 13
FIG. 5 SIGNALING PROTOCOL DECOUPLES THE SOFTWARE COMPONENTS OF THE GENERIC SOFTWARE FRAMEWORK 14
FIG. 6 THE SIGNAL-FUNCTION TABLE OF GSM TASK 22
FIG. 7 THE SOFTWARE ARCHITECTURE OF THE CREATED SOFTWARE FRAMEWORK 23
FIG. 8 THE GENERIC SOFTWARE FRAMEWORK 25
FIG. 9 CLASS DIAGRAM OF SIGNAL 27
FIG. 10 A SEQUENCE DIAGRAM OF MAKING A PHONE CALL 28
FIG. 11 A SEQUENCE DIAGRAM OF INCOMING CALL 29
FIG. 12 A CLASS DIAGRAM OF TASKS BASED ON THE TEMPLATE METHOD PATTERN 30
FIG. 13 MAILBOX DESIGN PATTERN BASED ON THE STRATEGY PATTERN 34
FIG. 14 SEQUENCE DIAGRAM: TASK1 SEND A SIGNAL TO TASK2 35
FIG. 15 SEQUENCE DIAGRAM: TASK2 FETCH A SIGNAL FROM ITS MAILBOX 35
FIG. 16 COLLABORATION DIAGRAM: UI TASK 36
FIG. 17 COLLABORATION DIAGRAM: MMI KERNEL TASK 38
FIG. 18 INTERNAL STATES OF MMI KERNEL TASK 39
FIG. 19 COLLABORATION DIAGRAM: MAKING A PHONE CALL 41
FIG. 20 COLLABORATION DIAGRAM: TAKE A SNAP SHOT 42
FIG. 21 STATES DIAGRAM OF KEYPAD ISR 43
FIG. 22 THE LOOK AND FEEL OF THE SIMULATOR 45
FIG. 23 THE SOFTWARE ARCHITECTURE OF THE SIMULATOR 46
FIG. 24 CREATE A SOFTWARE DESIGN FRAMEWORK FOR SIMULATOR 47
FIG. 25 THE PROGRAM GENERATOR COMBINES THE USER LOOK AND FEEL WITH THE DESIGN SOFTWARE FRAMEWORK 48
FIG. 26 THE SIGNAL FLOW OF DIALING A CALL 49
FIG. 27 THE SIGNAL FLOW OF INCOMING CALL 50
FIG. 28 THE SIGNAL FLOW OF ACCEPTING A CALL 51

Chapter 1

Introduction

1-1 MMI overview

The mobile device has become more and more popular in our daily life. In 2003, five hundreds million of handsets are sold. This number is increasing both in the year of 2004 and 2005 [2]. This big market attracts so many companies to join into this competition.

Each handset device has its own Man-Machine Interface (MMI), which allows users to operate on it. The Man-Machine Interface of a hand-held device is the “layer” that separates the machine and users [3]. A well-designed MMI can let people quickly understand the functionalities of the handset, and operate the handset easily. Hence, the look-and-feel of the MMI of a machine makes great impression on users. It is an important consideration for most users to choose a new handset.

1-2 Problem Statements & Motivation

The most of effort spent on the handset devices development is the MMI design and implementation. For those handset manufacturers, the user look and feel of the device is also an important consideration for new model release.

The current approach for creating MMI has limited flexibility to the changes of look and feel requirements. The current approach for creating MMI includes the following three processes:

1. Define the MMI requirements. Deliver the UI requirement specification to programmers.

2. Implementation. Programmers implement the MMI according to the scenarios, and create a ROMable application.
3. Verification. Verify the behaviors of MMI on handset device.

The UI designer usually describes the MMI requirement in the text-based format. Sometimes, both system designer and programmer have difficulty in understanding the requirement specification. The operative MMI cannot be seen until the UI system program has been implemented. In addition, once the UI requirement is changed, programmers have to change their handcrafted application code again.

There are some approaches proposed to ease UI design and implementation. In [1], an authoring tool can help UI designers to develop the MMI of a handset device. It provides a visual requirement authoring system and a program generation methodology to develop MMI for handset devices [1]. In this thesis, we propose a generic software framework to generate a software framework for the system architecture design of handset devices. The program generator glues the generated software framework with the user look and feel generated by the authoring tool and the application function generated by the function generator framework. Fig. 1 shows the concept diagram of this approach. We will discuss the details of this approach in chapter 3.

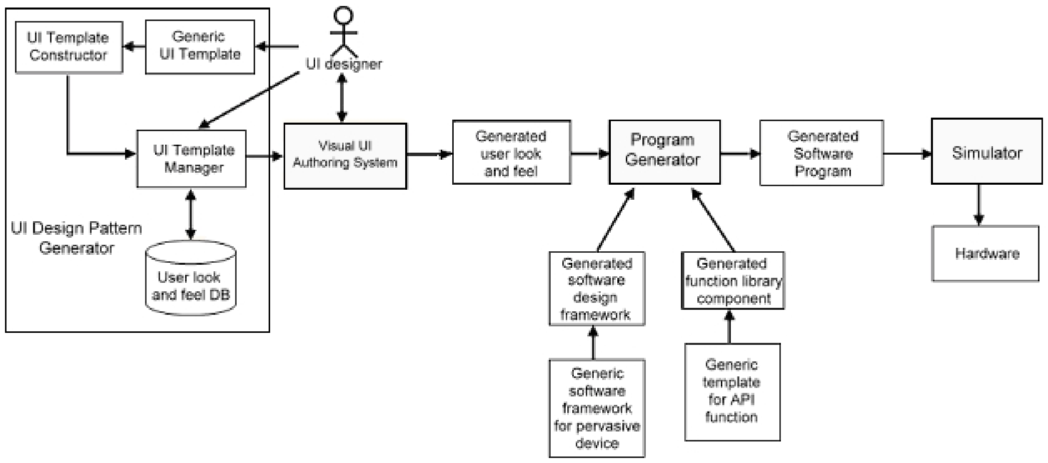

UI Template Constructor
Generic UI Template
UI designer
UI Template Manager
UI Design Pattern Generator
User look and feel DB
Visual UI Authoring System
Generated user look and feel
Program Generator
Generated Software Program
Simulator
Hardware
Generated software design framework
Generated function library component
Generic software framework for pervasive device
Generic template for API function

Fig. 1 Framework of UI Design Pattern Generator and

Visual Based Software Construction Model

1-3 Overview of this thesis

In Chapter 1, we introduce the concept of Man Machine Interface and describe the motivation of this research. Chapter 2 describes the related researches of the concept of software framework, the current software framework of handset devices, and the current method for creating MMI for handset devices. In Chapter 3, we propose a generic software framework that can be used to generate the software architecture of handset devices. In chapter 4, we will discuss how to instantiate a software framework from the generic software framework. Specifically, we create a software framework and construct a simulator. In chapter 5, we discuss the design and implementation of the generic software framework. In chapter 6, we will give several application examples to verify the feasibility and the applicability of the generic software framework. We implemented a software simulator for PC simulation. In chapter 7, we will summarize the study of this thesis.

Chapter 2

Software Framework for Handset Device and Related Work

In this chapter, we will introduce the related work of software framework, the concept of the software framework, and the current software framework of handset devices. We will elaborate each building block in the framework and address the current method for creating MMI.

2-1 Framework

A framework is a reusable, "semi-complete" application that can be specialized to produce custom applications for specific user domain [4]. It is not a finished work, but rather than a semi-finished software system that intended to be instantiated. A framework defines the architecture for specific application domain and provides the basic building blocks to create them [5].

In [6], it gives a good definition and explanation on framework and is recalled here:

*A framework consists of **frozen spots** and **hot spots**:*

- ***Frozen spots** define the overall architecture of a software system. For all instantiation of the application framework, the basic building blocks and the relationships between them remain unchanged (frozen).*
- ***Hot spots** are designed to be adapted to the needs of the application under development. When the programmer instantiates a software system from a software framework, he/she must specialize the hot spots of the software framework according to the specific needs and requirements of the system.*

One of the primary benefits of software frameworks is "Inversion of control". The framework reacts with external events. When events occur, the dispatcher of the framework *invokes the user-defined function to handle the event. This is also known as the Hollywood Principle: "Don't call us, we'll call you." [7].*

2-2 The current software framework for handset devices

In the current development method, the building blocks in the design software framework can be schematized as Fig. 2:

1. Man-Machine Interface (MMI) and relative functions
2. Real-time OS (RTOS) and Kernel Interface (KI)
3. GSM sub-system includes protocol stack and layer 1 driver.
4. Hardware devices and device drivers

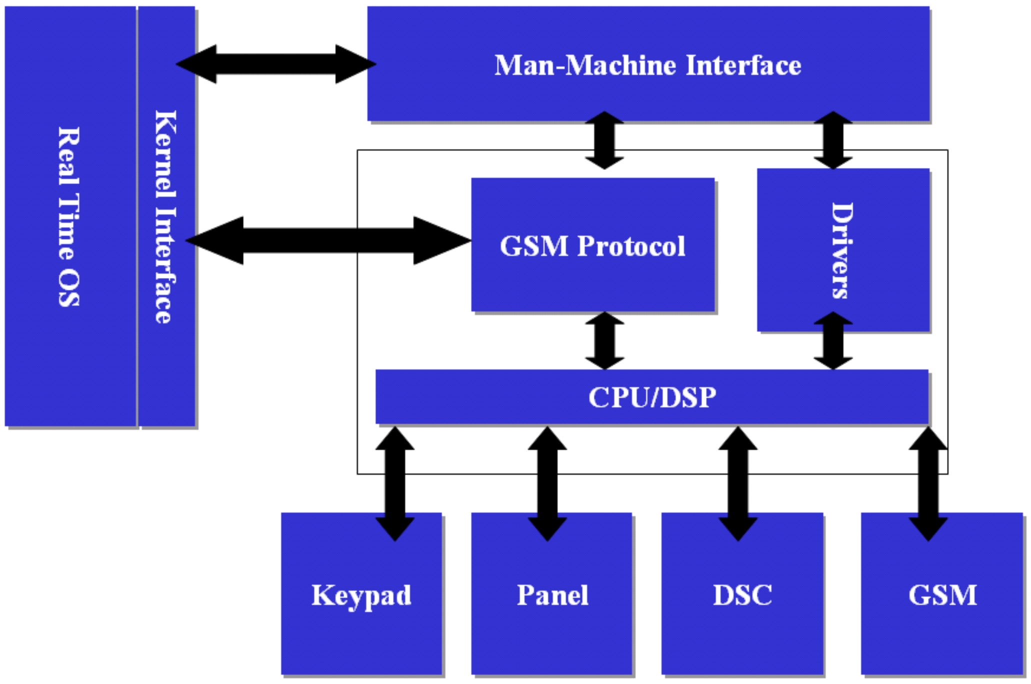


Fig. 2 The current software framework for handset devices

The responsibility of each building block is described in the following subsections.

2-2-1 Man-Machine Interface (MMI)

The MMI reacts with external events. It accepts input events and executes corresponding functions. External event include:

1. User input – key press.
2. Connection – originate a call, incoming call.
3. Handset status – battery status, antenna status, timer, etc.

The MMI also has the responsibility to represent the MMI scenarios on the display device of handset. The MMI includes a set of scenes. Icons, buttons, and pictures compose each scene. The external events trigger the changeover of scenes according to the current scenario.

2-2-2 Real-time operation system (RTOS)

The RTOS provides resource management services to application system. These services include:

1. Multithreading management.
2. Communication – mailbox, queue.
3. Synchronization – event, semaphore, mutex.
4. Interrupt service routines.

In a good system design, one usually forbids the application system to accesses the OS resource services directly. Instead, application system accesses the OS resource services via a wrapper – the Kernel Interfaces. The kernel interface is a set of predefined functions, which abstract the implementation details of OS services, and provides a stable interface to application system. Using this approach for system implementation will be easy for porting to another OS platform.

2-2-3 GSM subsystem

The GSM sub-system in the framework handles the communication task of the handset. The European Telecommunications Standards Institute (ETSI) defines standards of the GSM cellular phone system [8]. All GSM protocol must conform to the GSM standard to ensure the communication functionalities.

The ETSI also defines standards to extend the ITU-T Recommendation V.250. In the ITU-T Recommendation V.250, it codifies the most common commands used by DTE to control DCE with asynchronous DTE-DCE connections [9]. This is as known as "AT command set", because each command is started with "AT". PC uses the AT command to control its modem. For example, PC dials a phone by sending a string "ATD4125678" to modem.

These standards define a simple interface to control the GSM system. Any software can use the AT command to control the GSM system regardless of the complexity of GSM specification.

2-2-4 Hardware devices and drivers

Hardware device drivers included in the framework depend on the functional features provided by the handset device. The most common handset devices incorporated in the current cellular phone include:

1. Panel (display device).
2. Keypad (input device).
3. Digital camera (image capturing device).

The panel is the main display device of a handset. Application of the handset calls the panel drivers to draw on the panel. When the design of a handset device phases in a new type of panel, the programmers have to modify the program that relative to panel drivers.

The keypad is a basic input device of a handset. The interrupt service routine (ISR) of the handset is installed to the interrupt vector table of the target system. When the user press the key of handset, the processor of the target device will execute the keypad ISR.

The digital camera provides the function for capturing digital images. The digital camera for handset devices has various kinds of specifications. Programmers have to modify the relative program when the design of digital camera has been changed.

In the current software framework for handset devices, the signaling protocol decouples the relationship between the device drivers and the software applications. We will briefly describe the signaling protocol in next subsection.

2-2-5 Signal

The signaling protocol decouples the software application and the hardware devices. In the current framework for handset devices, we design several tasks to handle the hardware devices. Each task is a software component that provides an interface to access the hardware services. The interface is signaling protocol. The software applications of a handset device do not access the device drivers directly, but send signals to the relative task to request for hardware services. The task handles these requests by executing the corresponding driver functions.

Chapter 3

The Visual-based Software Construction Approach

And Generic Software Framework

In chapter 2, we have stated the problems of current development method for creating MMI. In this chapter, we will discuss how the authoring system and the generic software framework help programmers to develop the software application for handset devices.

3-1 The visual-based authoring system

In this section, the framework of a Visual Based Software Construction Model [10] is recalled and a UI design pattern generator is shown in Fig. 3.

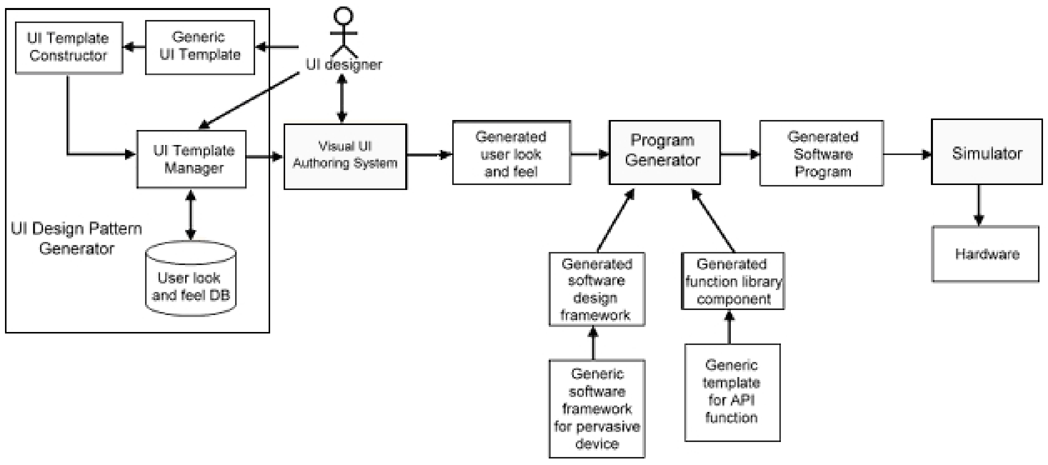

UI Template Constructor
Generic UI Template
UI designer
UI Template Manager
Visual UI Authoring System
Generated user look and feel
Program Generator
Generated Software Program
Simulator
UI Design Pattern Generator
User look and feel DB
Generated software design framework
Generated function library component
Hardware
Generic software framework for pervasive device
Generic template for API function

Fig. 3 The of UI Design Pattern Generator and Visual Based Software Construction Model

The Visual Based Software Construction approach supports a Visual Requirement Authoring system for UI designers to produce GUI based requirement scenario and specifications. It also supports a *Program Generator* to generate the target application system as specified in the visual requirement representation. The programmer can produce the target application system base on the function binding features provided in the program generator to bind each GUI component with the associated application function [10] [11].

This visual-based construction approach includes the ***Visual UI Authoring System***, which is used to edit the visual representation; the ***Program Generator***, which is used to generate the source code for target platform according to the visual representation generated by the visual UI authoring system; and the ***Simulator***, which is used for software simulation. The main components of this system are described as follows:

Visual UI Authoring System**:** It is a visual-based editor. The UI designers use the Visual UI Authoring System to create a prototype of user look and feel. Then one can edit this prototype by adding more text or buttons. The UI designers can preview the prototype and modify it. After the authoring is completed, the UI designers have generated the target UI system.

Program Generator**:** A function binding system generates the program for target system. When the design of user look and feel is satisfied, the UI designers use the program generator to produce the source code of application. The program generator produces the source code according to the visual representation generated by the Visual UI Authoring System. The program generator glues the UI components to the software design framework, and binds function library component with each UI component defined in the generated visual representation.

Software design framework**:** The program generator applies the software design framework to generate the source code. A software framework is a platform for representing the visual representation that is generated by the authoring system. Programmers can instantiate a software framework from the generic software framework. We will discuss the generic software framework in section 3-2.

Function library component: It is a set of pre-defined library. Programmers implement this function library according to the hardware specification. The program generator applies the function library to produce source code for MMI. The function library component is generated by generic template for API function that will be elaborated in [12].

***Simulator*:** It is used to simulate the functionalities of the generated target application software on the target cellular phone. Programmers can verify the requirement of the generated software application on PC. If the requirement of the generated software application is fulfill, then one can build the firmware for the target system, download the firmware to the target device, and verify the behavior of the application on target platform.

The UI designer can use the Visual UI Authoring System to edit the user look and feel. He or she can author the user look and feel to produce a visual representation for the target platform. Then the program generator produces the source code for target platform according to the produced visual representation. It generates source code by gluing the software design framework to the library functions. Finally, one uses the simulator to do software simulation.

This visual UI authoring system is especially suitable for the UI designer. The Visual-based authoring system helps the UI designers to create a prototype of MMI in an efficiency way. The designers can edit and preview this prototype and verify its functionality on PC. After the design of MMI is frozen, the UI designer can apply this authoring system to produce the target UI program without writing any textual code. The authoring system uses the code generator to translate the visual representation to source code. The code generator resolves the relationship between the MMI and the functions of device drivers. It applies the designed framework and function library in code generation phase.

3-2 Methodology for using a software design framework to create software applications for handset devices

In this section, the methodology for using a software design framework to create software applications for handset devices is recalled [1] here:

The user look and feel and the application function are glued with the instantiated software framework in the code generation phase. When the design of user look and feel is satisfied, the programmer can use the *AP function and UI binder* and the *Application system program generator* to generate the software application program for target platform. The code generation has two phases:

1. *AP function and UI binder:*

   The AP function and UI binder glues the application function with the instantiated software framework. After the visual representation has met the requirement of user look and feel, the programmers choose function library components to complete the function binding. A function library component is a software component that provides an interface to drive the specific hardware devices. The programmers bind the actor of a scene with the selected function of a function library component.

2. *Application system program generator:*

   The program generator glues the user look and feel with the instantiated software framework. When the function binding is completed, the program generator translates each scene of the user look and feel to code snips. The program generator collects these code snips and glues them with the program of instantiated software framework.

After the function binding and program generation are completed, the program for target platform is generated. To verify the conformance of the program that was generated from the program generator, the programmers have to compile the program and make an executable image for the target platform.

In this research work, we focus in the program generator. Specifically, a generic software framework for handset devices is proposed to generate the target software design framework. In the following section, we present the architecture of the generic software framework.

3-3 Architecture of the generic software framework

The generic software framework for handset devices is a multitasking, event-driven system. There are eight parts in the generic software framework, as shown in Fig. 4: the **signaling protocol** is the inter-task communication interface for software component; the **UI task** represents the MMI scenarios; the **MMI kernel task** listens to events and dispatches events to corresponding tasks; the **GSM task** handles the GSM-related events and provides communication services; the **DSC task** handles the digital camera; the **keypad ISR** report keypad event to the MMI kernel task; the **Display API** defines a set of functions which the UI task use to draw on panel; the **GKI** class library provides the functionalities to create these tasks and defines the interface of signaling protocol.

The MMI kernel task acts as the 'headwaiter' in the generic software framework. The other tasks act as 'waiters': they accept request signals sent from MMI kernel task and perform services by executing application functions.

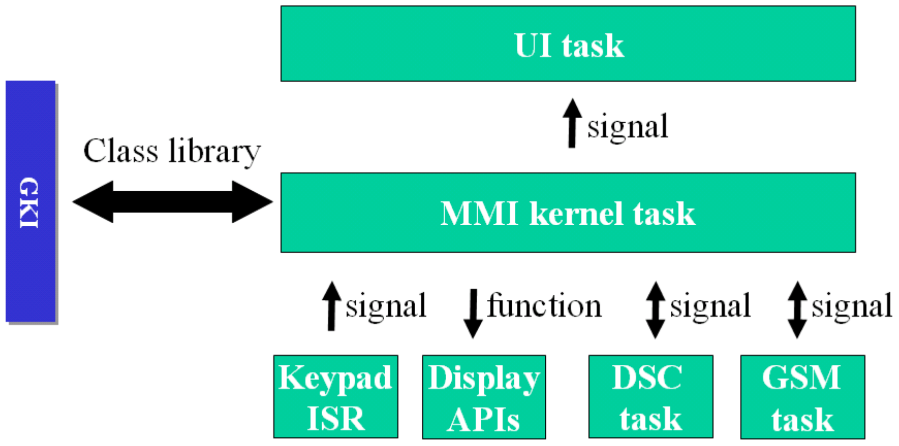
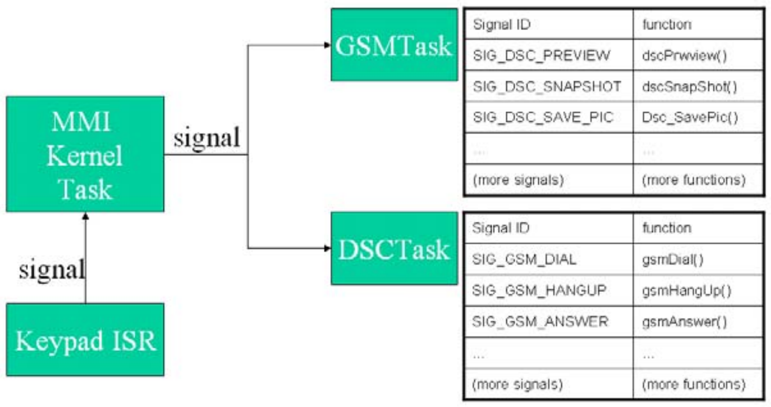


Fig. 4 The generic software framework

Signaling protocol is an inter-task communication and synchronization mechanism in the generic software framework. There are four tasks in the generic software framework: *UI task*, *MMI kernel task*, *GSM task* and *DSC task*. Each task is a software component that provides pre-defined services. A task accesses the other task's services via an interface, the signaling protocol. The MMI kernel task requests hardware services by sending signals to other tasks. Note that the MMI kernel task does not call the driver functions directly. This means the generic software framework provides a hardware-independent platform for software applications. The signaling protocol decouples the interfaces and implementations of the hardware devices, as shown in Fig. 5:



Signal ID	function
SIG_DSC_PREVIEW	dscPrwview()
SIG_DSC_SNAPSHOT	dscSnapShot()
SIG_DSC_SAVE_PIC	Dsc_SavePic()
...	...
(more signals)	(more functions)

Signal ID	function
SIG_GSM_DIAL	gsmDial()
SIG_GSM_HANGUP	gsmHangUp()
SIG_GSM_ANSWER	gsmAnswer()
...	...
(more signals)	(more functions)

Fig. 5 Signaling protocol decouples the software components of the generic software framework

Each task has a mailbox for storing signals. The interfaces of sending and receiving signals to each other are the same. The behavior to process signal depends on each task.

The **UI task** represents the MMI scenarios that generated by the program generator. It displays the contents of the current scene on panel. The MMI kernel task request the UI task to change the scene by sending signals. The UI task processes these signal by redrawing the content of the current scene on the panel.

The **MMI kernel task** acts as an “event listener” and “event dispatcher” in the generic software framework. It listens to external events and dispatches events to corresponding event handlers, such as UI task, GSM task and DSC task. The MMI kernel task dispatches jobs to these tasks by sending signals to them.

The **GSM task** is a software component that handles the GSM sub-system and provides a stable interface via the signaling protocol. The MMI kernel task requests for the GSM services by sending signals to GSM task. The GSM task reports the communication status by sending signals to MMI kernel task. The interface of the GSM task and GSM-sub-system is the AT command interface, which is defined in [8] and [9]. The GSM task must conform to the signaling protocol to provide the services of GSM sub-system.

The **DSC task** is a software component that handles the digital camera hardware. It controls the DSC module to perform the services of preview, snapshot, and so on. The DSC task must conform to the signaling protocol of the generic software framework. The details of DSC can be found in [12].

The **Keypad ISR** handles the key press events and reports it to MMI kernel task. The keypad is a basic input device of a handset. The keypad ISR is registered to the interrupt target system. When a user presses the key, a hardware interrupt triggers the CPU to execute the keypad ISR to send a signal to MMI kernel task.

The **Display API** is a set of service routine that implements the drawing functions on the panel of handset device. The UI task uses these functions to draws pictures, buttons and icons on panel. The implementation of Display API depends on the hardware device. A complete study of Display API is beyond the scope of this thesis.

The **Generic Kernel Interface** (**GKI**) is a class library that wraps the OS. It encapsulates the implementation of OS, such as multitasking, inter-task communication and synchronization, and provides a stable interface for software application. When the programmers port the application to another OS, they do not need to modify the software application, but only need to rewrite the GKI library. Each task in the generic software framework is a sub-class of GKI Task class. The GKI class library implements the functionality of signaling protocol.

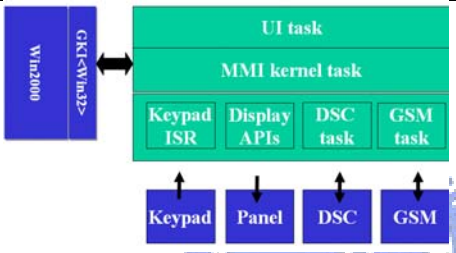
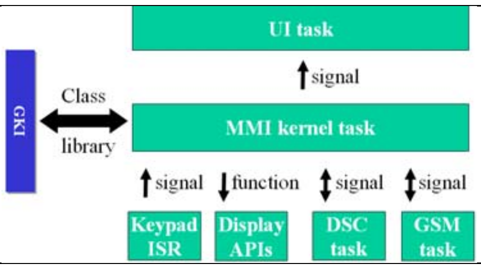
In the next section, we present a comparison study between the software framework and generic software framework.

3-4 A comparison between software framework and generic software framework

A software design framework is a reusable architecture for creating software applications for handset devices. A generic software framework is a template of software design framework. A software design framework is specialized to target OS and hardware device, where the generic software framework defines these interfaces and left the implementation issues for software framework.

The generic software framework provides a template for implementing the software design framework for specific OS and hardware device. It defines the algorithm to access the services of OS and hardware device drivers. The software design frameworks overwrite to provide concrete behaviors. Table. 1 gives a comparison between software framework and generic software framework from different aspects:

Table. 1 A comparison between software framework and generic software framework.

	Software Framework	Generic Software Framework
Software architecture	 Win2000 GKI<Win32> UI task MMI kernel task Keypad ISR Display APIs DSC task GSM task Keypad Panel DSC GSM	 UI task signal GKI Class library MMI kernel task signal function signal signal Keypad ISR Display APIs DSC task GSM task
Concept	A reusable software architecture for handset devices.	A generic template of reusable software architecture for handset devices.
Flexibility	Provides an OS-dependent and hardware-dependent platform for handset devices.	Defines the generic methods to access the services provided by OS and hardware devices.
Components	Tasks, signaling protocol, GKI class library.	Same.
Implementation issues	Porting the GKI class library to target OS. Implement the tasks, keypad ISR and Display API for target device.	Provides the porting guidelines of GKI and tasks.
GKI	Specialized to the target OS platform.	Provides generic methods to access the services of OS.
Keypad ISR	Implemented for the keypad device of target system.	Defines the behaviors of keypad ISR for the MMI kernel task.
Display API	Implemented with the functions of the target panel device.	Defines the drawing functions for UI task.
DSC task	Performs DSC services by executing the functions of DSC device drivers.	Defines the generic behavior of DSC devices.
GSM task	Performs communication services by handling AT commands.	Defines the generic behaviors of GSM sub-system.

The visual-based UI authoring system helps to create the application based on the prerequisites of software design framework. The authoring system does not need to know the implementation details of OS and hardware device. The details are encapsulated behind the software design framework.

A more details treatment on the generic software framework for handset devices will be given in chapter 4 and chapter 5.

Chapter 4

Software Framework Generation

Based on Generic Software Framework

In chapter 3, we outline the structure of a generic software framework and present the major components description in generic software framework. In this chapter, we will discuss how to instantiate a software framework from the generic software framework.

4-1 Software framework generation based on the generic software framework

To create a software framework for handset device, the generic software framework must be specialized for target OS and hardware devices. The unresolved components headed to be instantiated in the proposed generic software framework include:

1. Generic Kernel Interface (GKI).
2. GSM task.
3. DSC task.
4. Keypad ISR.
5. Display API.

The details of DSC task can be found in [12], thus it is not elaborated here.

In addition, a complete treatment for the Display API is beyond the scope of this thesis. In the simulator, we use the Borland Visual Component Library (VCL) to implement the Display API for simulation purpose.

The program generator takes the generated software design framework to produce the target platform for the application program. A software design framework is a "user-defined specialization" instance of generic software framework. A software framework is specialized for a specific OS and hardware device after the following actions are taken:

1. Porting the GKI library to the target operating system. In the proposed generic software framework, in this case, the programmer need to overwrite the Task class to carry out this duty. We will give a porting example of Win32 platform in the chapter 5.
2. Porting the Keypad ISR for the keypad device of target handset. The Keypad ISR handles the key input events and report events by sending signals to MMI kernel task.
3. Porting the Display API for the panel device of target handset. The Display API allows application to draw image and text on panel.
4. Implement the GSM task according to the signaling protocol. The communication request and report of the status to MMI kernel task will be defined here.
5. Implement the DSC task according to the signaling protocol. The DSC task that handles the DSC module will be defined here. The details can be found in [12]

In following sections, we will discuss how to instantiate the generic software framework to create a target software framework.

4-2 Generic Kernel Interface (GKI)

In this section, we will explain how to port the GKI class library to a target OS. At first, we briefly introduce how to create a thread. The Task composites a Mailbox to store signals. We will discuss the implementation principle of mailbox. After the Task create a thread, it is able to send signals and receive signals. The `sendSignal` and `recvSignal` are introduced at last. Here we give examples that porting the GKI to the Win32 OS platform. We implement all samples in this section in C++ language.

The Generic Kernel Interface is designed to adapt the application to different OS platform. There are three major steps in this porting process:

1. Implement the *Task* class for multi-tasking.
2. Implement the *Mailbox* for sending and receiving signals.
3. Overwrite the `sendSignal` and `recvSignal` methods of Task class.

4-2-1 Task

To create a thread on Win32 platform, one has to prepare the entry function **`start_address`** for thread execution and the parameter **`arglist`** for entry function. Then call the `_beginthreadex` to create a thread [13]. According to C++ specification, when we assign a method of Task to `start_address`, the method must be **static,** as shown in the following Program sample 1.

```
unsigned long _beginthreadex(
   void *security,
   unsigned stack_size,
   unsigned ( __stdcall *start_address )( void * ),
   void *arglist,
   unsigned initflag,
   unsigned *thrdaddr );
```

Program sample 1

We call the `_beginthreadex` in the `Task::start` method [14] [15]. Here we pass “**this**” to the `_beginthreadex` as the parameter of entry function, as shown in Program sample 2:

```
bool Task::start()
{
   hThread = _beginthreadex(NULL, 0, entryFunc, (LPVOID)this,
                                    0, &dwThreadID);
}
```

Program sample 2

When the `start` method of the Task class is invoked, it will call the OS service routine to create a thread for the current application program. The thread will take the pointer of the Task object as parameter (**`this`**) and execute the entry function `entryFunc`.

Porting the Task class to another OS is in the same manner. Call the OS API to create a thread in the `Task::start` method, and keep the thread handle for later manipulation.

4-2-2 Mailbox

The mailbox is a common concept among RTOS. Most RTOS has ready-made solution of mailbox. If there is not a suitable solution for mailbox, it is still easy to implement a Mailbox class. Here is the guideline to implement a mailbox:

1. A mailbox provides methods for operating signals:
   ```
   bool empty(void);
   Signal * front(void);
   void push(Signal *);
   void pop(void);
   ```

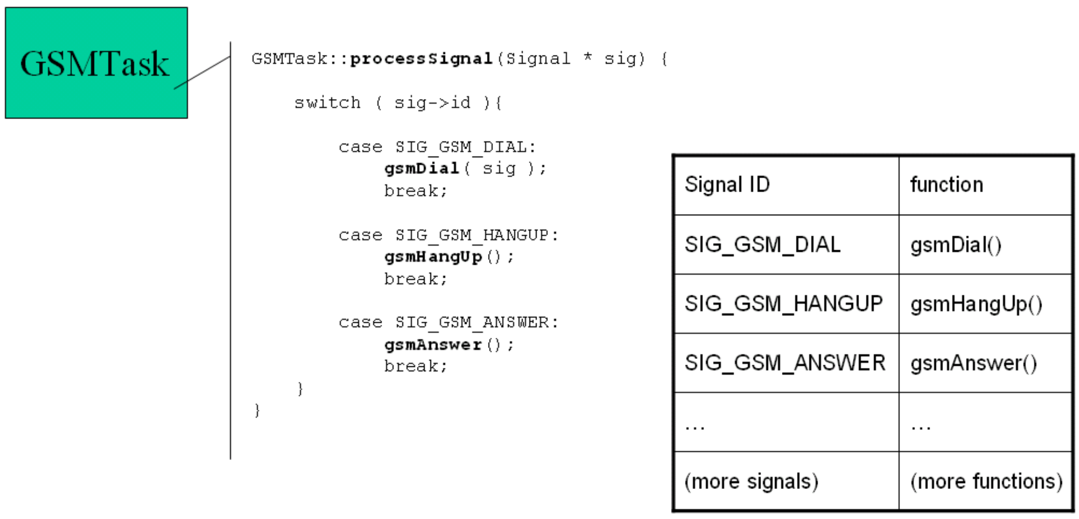
2. A mailbox composites a queue to hold signals:
   ```
   queue<Signal *> signalQueue;
   ```

3. The mailbox provides a `wait` method to prevent from pooling signal queue. When the `wait` method is called, the calling task will be blocked until a signal is available:
   ```
   void wait(void);
   ```

4. An atomic-lock guards the signal queue to prevent from synchronous access.

4-3 GSM task

The GSM task is a software component that provides the GSM communication services in the generic software framework. It encapsulates the GSM sub-system and provides GSM service via the signaling protocol. All signals send to GSM task will be processed in the `processSignal` method. To implement a GSM task to handle the target GSM module, one has to overwrite the `processSignal` method of the GSM task. We will illustrate the concept of overwriting the `processSignal` method of GSM task in Fig. 6.



```
GSMTask::processSignal(Signal * sig) {

    switch ( sig->id ){

        case SIG_GSM_DIAL:
            gsmDial( sig );
            break;

        case SIG_GSM_HANGUP:
            gsmHangUp();
            break;

        case SIG_GSM_ANSWER:
            gsmAnswer();
            break;
    }
}
```

Signal ID	function
SIG_GSM_DIAL	gsmDial()
SIG_GSM_HANGUP	gsmHangUp()
SIG_GSM_ANSWER	gsmAnswer()
…	…
(more signals)	(more functions)

Fig. 6 **The signal-function table of GSM task**

To overwrite the `GSMTask::processSignal`, we have to pair the corresponding device functions for each kind of incoming signal. There exists a relationship between the type of signal and the corresponding function. Each kind of signal stands for a corresponding GSM service. We show the signal-function as a table in the right hand side of Fig. 6. Programmers can provide more services to GSM task by adding more signals and functions in the `GSMTask::processSignal` method. The parameters for calling the functions are attached in the context of signal. The GSM task retrieves the parameters from the signal and pass these parameters to the AT command interface.

4-4 Keypad ISR

The Keypad ISR is executed on the key press interrupt. Each time the key is pressed, the processor executes the Keypad ISR to send a signal to MMI kernel task. To create a keypad ISR for target software framework, one must implement the keypad ISR and register the keypad ISR on the interrupt vector table of the target system.

4-5 The created software framework

When the GKI class library is ported to the target OS, and the GSM task, DSC task, and keypad ISR are all implemented for a specific hardware device, the hot spots of the generic software framework are resolved, thus, a software framework is created. Fig. 7 schematizes the overview of the software architecture of the created software framework:

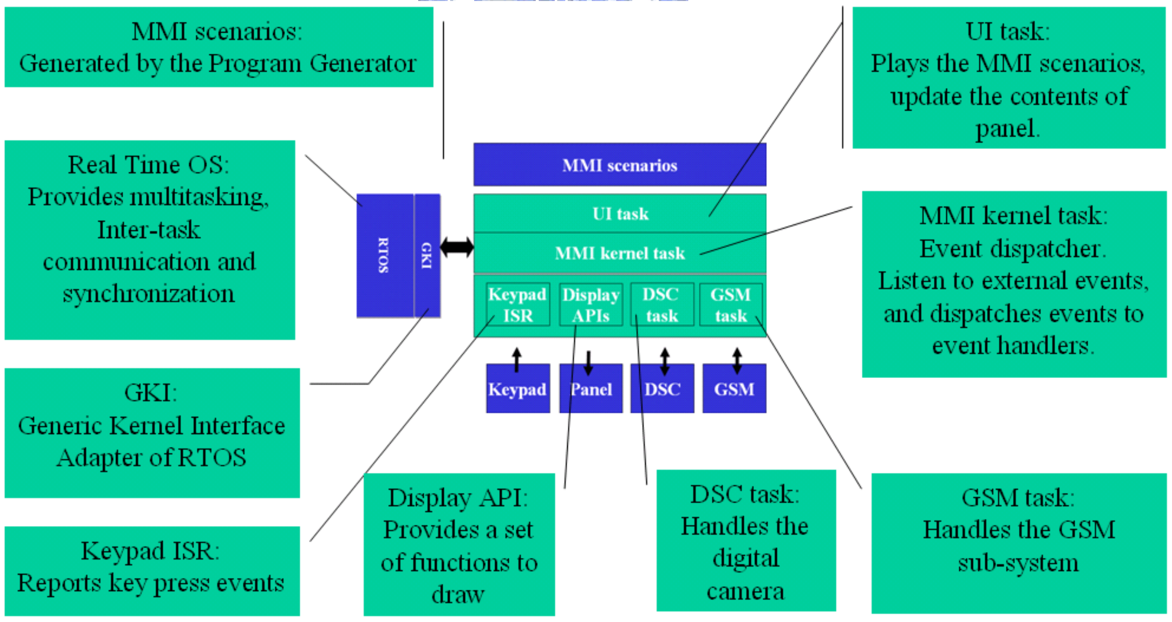

MMI scenarios: Generated by the Program Generator
Real Time OS: Provides multitasking, Inter-task communication and synchronization
GKI: Generic Kernel Interface Adapter of RTOS
Keypad ISR: Reports key press events
Display API: Provides a set of functions to draw
DSC task: Handles the digital camera
GSM task: Handles the GSM sub-system
MMI kernel task: Event dispatcher. Listen to external events, and dispatches events to event handlers.
UI task: Plays the MMI scenarios, update the contents of panel.
RTOS
GKI
MMI scenarios
UI task
MMI kernel task
Keypad ISR
Display APIs
DSC task
GSM task
Keypad
Panel
DSC
GSM

Fig. 7 The software architecture of the created software framework

The created software framework provides a platform for representing the MMI scenarios generated by the visual-based UI authoring system. The GKI class library wraps the operating system and provides the functionalities for creating tasks and signaling protocol. The UI task can represent the MMI scenarios generated by the visual-based UI authoring system. The MMI kernel task interacts with input events and dispatches signals to other tasks. The Keypad ISR is invoked to report the key press events when user presses the keypad. The UI task uses the Display API to draw images on panel. The DSC task handles the DSC module. The GSM task controls the GSM sub-system.

Chapter 5

System Design and Implementation

In chapter 4, we have discussed the software architecture of generic software framework. In this chapter, we describe the design and implementation details of the generic software framework. The design and implementation of GKI class library, the UI task, MMI kernel task, GSM task, DSC task, and Keypad ISR are discussed in the following sections.

The software architecture of the generic software framework is recalled and is shown in Fig. 8.

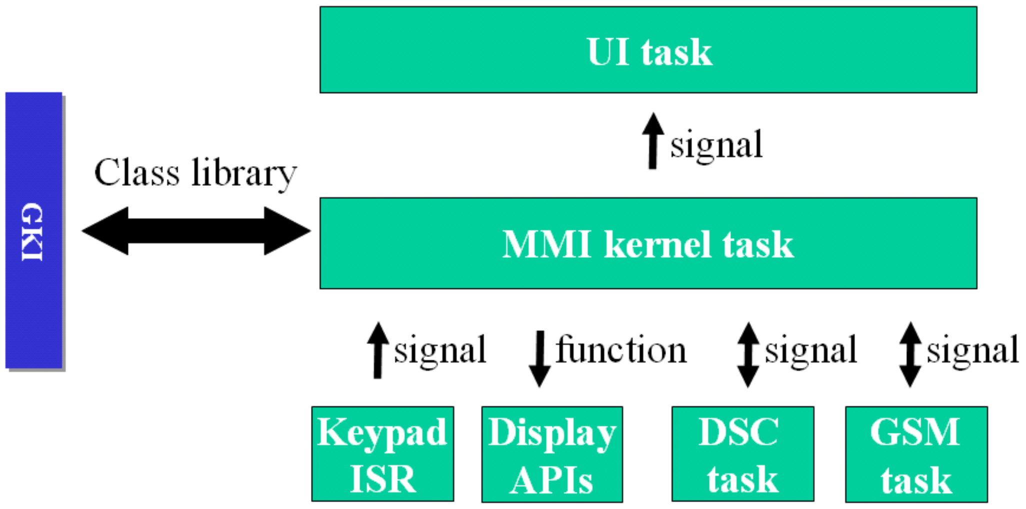


Fig. 8 The generic software framework

5-1 Design and Implementation of Generic Kernel Interface (GKI)

GKI is a class library that provides functionalities of multitasking, inter-task communication, and synchronization that are implemented by the synchronized objects. The synchronized objects - such as mutex, critical section, lock, and semaphore - are platformdependent. In this study, we use C++ to implement the multitasking, threads, and thread safety [16].

We implement these synchronized objects as the wrapped objects for the platform independent consideration. In this study, when we need to port the program to another platform, we will not need to restructure our codes, but only need to rewrite these synchronized classes.

We implement several synchronized objects to construct the GKI class library:

1. **Signal** - Tasks communicate to each other via signals.
2. **Task** - GKI provides the Task class to create tasks. The implementation details for creating tasks on different OS are encapsulated in the Task class.
3. **Mailbox** - Stores signals. Each task has its own mailbox.

Each Task in the GKI has a mailbox to store signals. Both the `sendSignal` and `recvSignal` of the Task class are relevant to mailbox. The following Program sample 3 shows the relationship between Task, Mailbox and Signal:

```
Task::sendSignal(Signal * sig)
{
    mailbox.push(sig);
}

Signal * Task::recvSignal()
{
    mailbox.wait();// wait until a message is received.
    Signal * sig = mailbox.front();
    mailbox.pop();
    return sig;
}
```

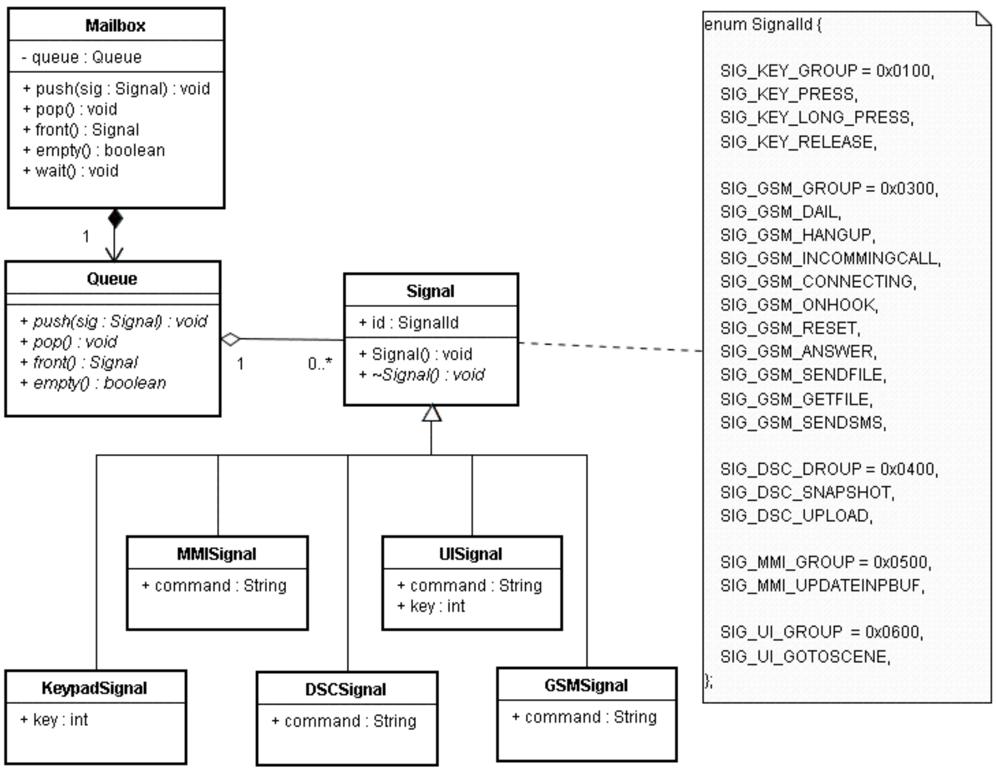
Program sample 3

5-1-1 Signal

In the generic software framework, signals are used for tasks to communicate and synchronize to each other. The MMI kernel task coordinates event invocations and event executions by using signals. When an external event is triggered, a signal is constructed and sends to MMI kernel task. The MMI kernel task will process these signals and dispatch them to other task.

Signals are stored in the mailbox of a task. Each task has a public method `sendSignal` for other task to send a signal to itself. The private method `recvSignal` fetches a signal from mailbox.

There are several kinds of signals in the generic software framework. Each type of signal is a sub-class of the **`Signal`** class. The Mailbox provides a method to push a signal into its internal queue and fetch a signal from queue. The Mailbox treats all kinds of signals in the same manner. We illustrate the Signal and the sub-class of Signal in Fig. 9.



```
enum SignalId {

  SIG_KEY_GROUP = 0x0100,
  SIG_KEY_PRESS,
  SIG_KEY_LONG_PRESS,
  SIG_KEY_RELEASE,

  SIG_GSM_GROUP = 0x0300,
  SIG_GSM_DAIL,
  SIG_GSM_HANGUP,
  SIG_GSM_INCOMMINGCALL,
  SIG_GSM_CONNECTING,
  SIG_GSM_ONHOOK,
  SIG_GSM_RESET,
  SIG_GSM_ANSWER,
  SIG_GSM_SENDFILE,
  SIG_GSM_GETFILE,
  SIG_GSM_SENDSMS,

  SIG_DSC_DROUP = 0x0400,
  SIG_DSC_SNAPSHOT,
  SIG_DSC_UPLOAD,

  SIG_MMI_GROUP = 0x0500,
  SIG_MMI_UPDATEINPBUF,

  SIG_UI_GROUP  = 0x0600,
  SIG_UI_GOTOSCENE,
};
```

Fig. 9 Class diagram of Signal

In order to represent each kind of external events, we define several types of signal, such as `KeypadSignal`, `MMISignal`, `DSCSignal`, `UISignal` and `GSMSignal`. These signals derive from the `Signal` class and overwrite the virtual destructor that is defined in base class. The Signal class defines the pure virtual destructor which derive classes provide a concrete implementation. When program deletes a signal, the destructor of the signal is invoked to release the resources contained in the signal.

A sub-class of `Signal` has a `SignalId` data field for identification and several data fields for storing messages. When a task receive a signal, it identifies the signal identification to decide what action to take, and obtains the parameters of functions from the messages.

Here we give two examples to explain the usage of signals.

The first example, as shown in Fig. 10, illustrates how signals are used to make a phone call. When user dials several numbers, the Keypad ISR sends a series of key-press signals to MMI kernel task. The MMI kernel task will send signals to trigger the UI task to update the current scene and redraw the scene on panel. After user press the OK key, the MMI kernel task will receive the signal, and send another signal to GSM task to make a phone call.

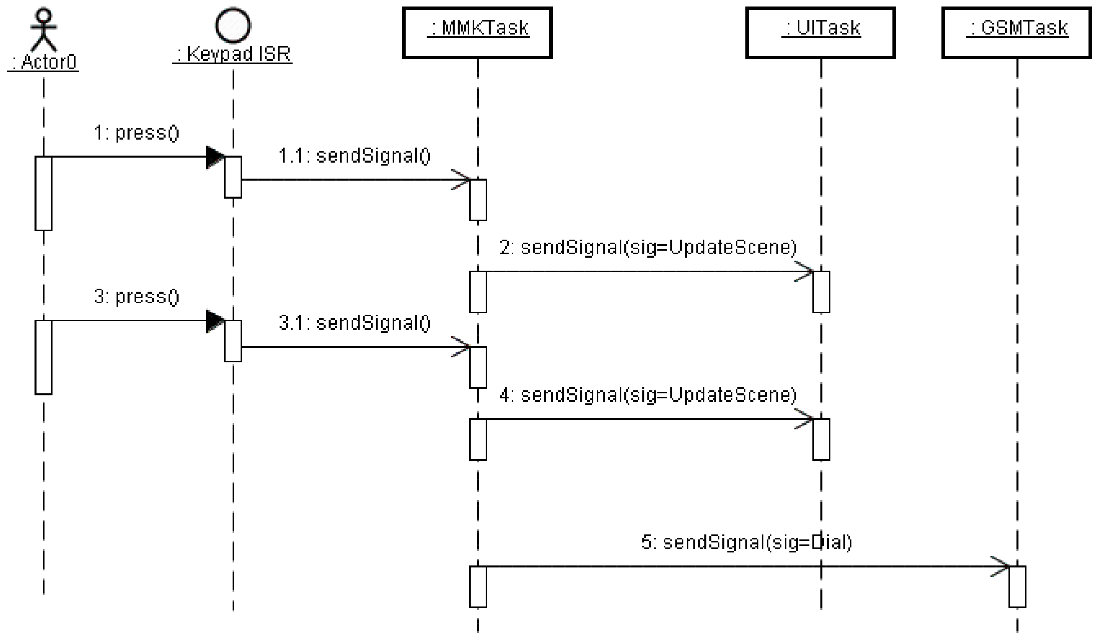


Fig. 10 A sequence diagram of making a phone call

Another example is given in Fig. 11 to show the sequence diagram of incoming call. When the GSM task is notified by incoming call, it sends an INCOMMING_CALL signal to MMI kernel task. MMI kernel task will send another signal to inform UI task to update the MMI scenario. After the user press the OK key to accept the call, a hardware interrupt is happened, and the corresponding interrupt service routine (ISR) is triggered to send a KEY_PRESS signal to MMI kernel task. Again, the MMI kernel task sends another signal to inform UI task to update the MMI scenario.

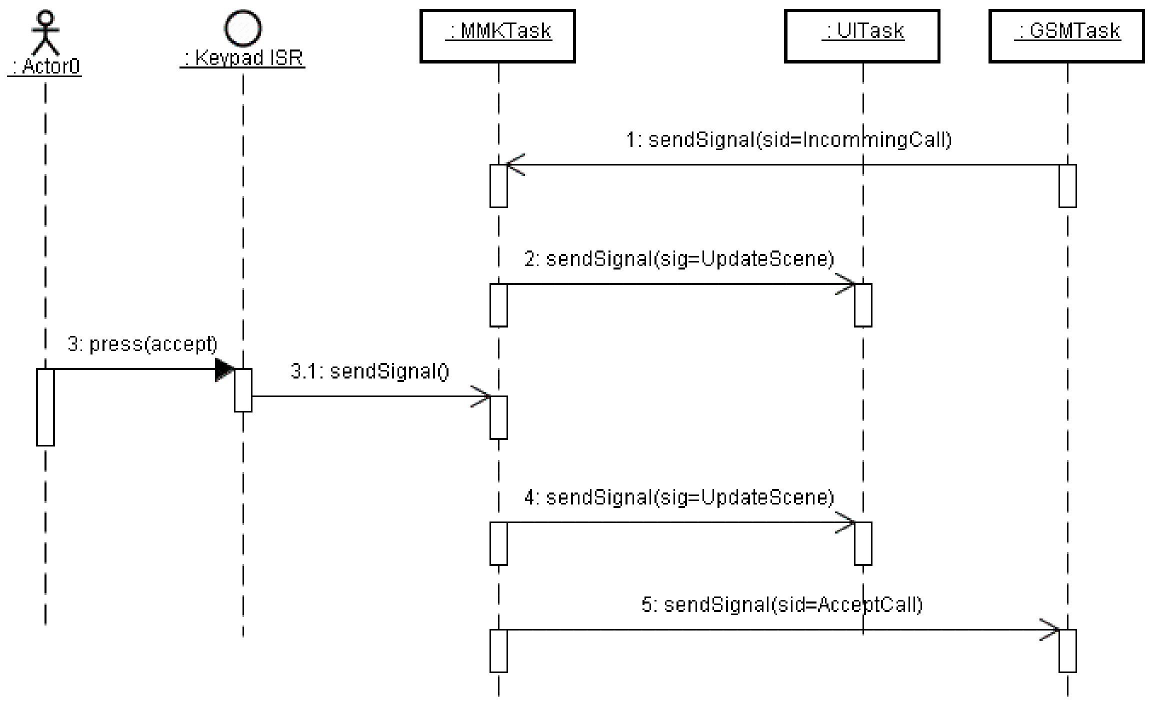
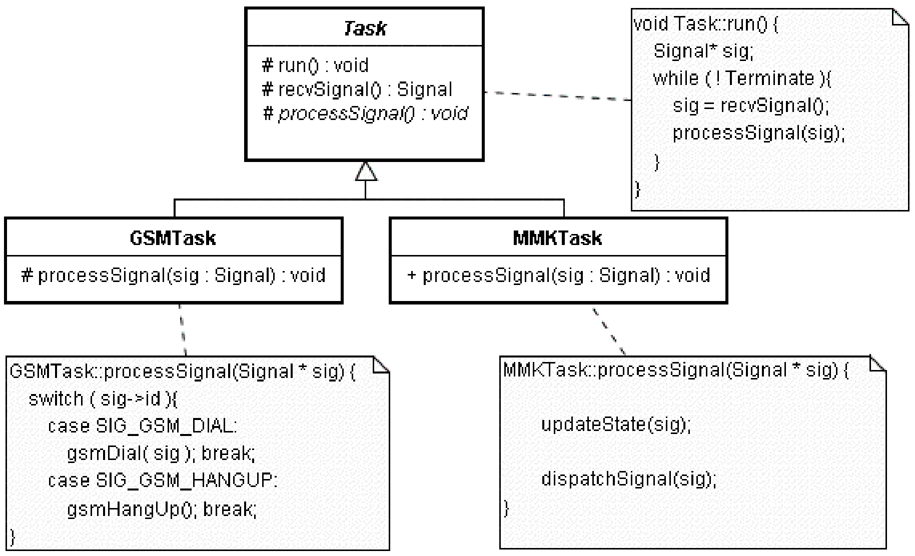

: Actor0
: Keypad ISR
: MMKTask
: UITask
: GSMTask
1: sendSignal(sid=IncommingCall)
2: sendSignal(sig=UpdateScene)
3: press(accept)
3.1: sendSignal()
4: sendSignal(sig=UpdateScene)
5: sendSignal(sid=AcceptCall)

Fig. 11 A sequence diagram of incoming call

5-1-2 Task

The *Task* class gives a skeleton for common behavior on multitasking, inter-task communication and synchronization. There are four tasks in the generic software framework, UI task, MMI kernel task, GSM task and DSC task. Each task is a sub-class of *Task* class. We use the Template Method pattern [17] to design the Task class and these sub-classes. Fig. 12 shows the design pattern of tasks using the Template Method pattern.



```
void Task::run() {
  Signal* sig;
  while ( ! Terminate ){
    sig = recvSignal();
    processSignal(sig);
  }
}
```

```
GSMTask::processSignal(Signal * sig) {
  switch ( sig->id ){
    case SIG_GSM_DIAL:
      gsmDial( sig ); break;
    case SIG_GSM_HANGUP:
      gsmHangUp(); break;
}
```

```
MMKTask::processSignal(Signal * sig) {

    updateState(sig);

    dispatchSignal(sig);
}
```

Fig. 12 A class diagram of tasks based on the Template Method pattern

The Task provides a template for those tasks defined in the generic software framework. It defines concrete methods that subclass can choose to reuse or overwrite; it defines primitive methods that the subclasses of Task must implement. The implementation policy of these primitive methods varies with OS and hardware device.

The Task class provides these methods:

```
1. bool start();
2. virtual void run();
3. public void sendSignal(Signal * msg);
4. protected Signal * recvSignal(void);
5. protected virtual void processSignal(Signal * msg) = 0;
6. protected virtual void destroySignal(Signal * msg) = 0;
```

The *`start`* is a concrete method that creates a thread for the current application.

The *`run`* is a template method that receives signals and process signals. Successors of Task may choose to overwrite this method and insert the code that should be executed, or reuse the default implementation.

The *`sendSignal`* is a concrete method that pushes a signal to its internal mailbox.

The *`recvSignal`* is a concrete method that fetches one signal from the mailbox. The recvSignal is a private method. This is because each task has its own duty to process signals, and this internal information need to be encapsulated into a task.

The *`processSignal`* is a primitive method that processes the signal that was sent to the task. The subclasses of Task must override this abstract virtual function based on the behavior of processing signal.

The *`destroySignal`* is a primitive method that releases the memory that is allocated for the signal. The subclass of Task must override this abstract virtual function to release the resources allocated for signals.

The concrete methods, `sendSignal` and `recvSignal`, provide the common interfaces to send and receive signals.

The abstract methods, `processSignal` and `destroySignal`, are left for derived classes to provide concrete implementations. The behavior to process signals depends on the requirement of each derived class.

When the start method is invoked, a thread is created. Here we give a program example to illustrate the algorithm of start method:

```
bool Task::start()
{
  hThread = _beginthreadex(
            NULL,
            0,
            entryFunc,
            this,
            0,
            &dwThreadID);
}
```

Program sample 4

The created thread will take the pointer of Task object as parameter and call the `entryFunc`. The entry function `Task::entryFunc` is a **static** method that accepts an argument - this, which is the only point to distinguish one task from the others. After the thread is created, the OS will execute the static `entryFunc` method in the context of thread.

In the `Task::entryFunc`, the program references the pointer of the Task object. After initialization, the program enters `run` method. When the task has completed its job, the program calls the exit to cleanup. The following program example illustrates the algorithm of `entryFunc` method:

```
unsigned __stdcall Task::entryFunc(LPVOID lpParameter)
{
  Task * pTask = reinterpret_cast<Task*>(lpParameter);

  pTask->initialize();
  pTask->run();
  return pTask->exit();
}
```

Program sample 5

The run method contains the user-defined program for the Task. The implementation of run method provides a default design for subclass of Task. In run method, tasks receive signals from its mailbox, and process signals in their primitive processSignal, here is a program example:

```
void Task::run()
{
    Signal * sig;
    while ( ! terminate ){
          sig = recvSignal();
          processSignal(msg);
    }
}
```

Program sample 6

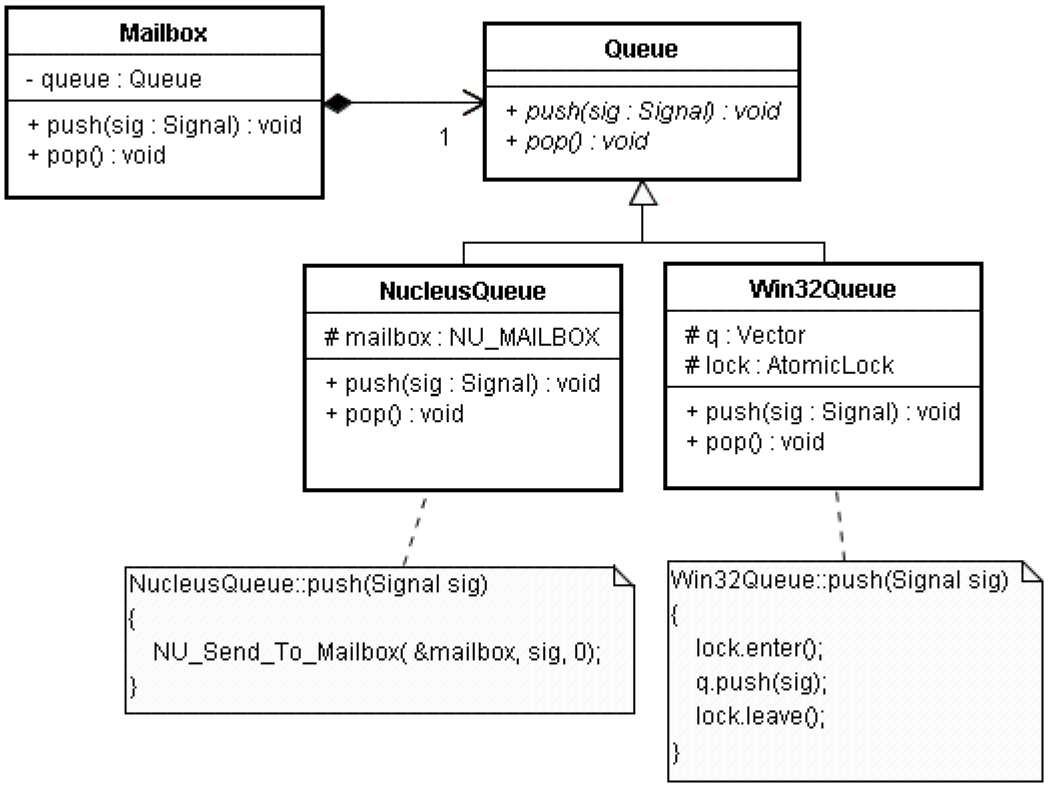
Programmers can choose to reuse this implementation or have another implementation for the subclass of Task. In UI task, GSM task, and DSC task, we choose to reuse the default implementation of `run` method defined in Task class. In the MMI kernel task, we choose to overwrite this default implementation. Following program example explains the overwritten `run` method of MMI kernel task:

```
void MMITask::run()
{
    Signal * sig;
    while ( ! terminate ){
          sig = recvSignal();
          updateCurrentState(sig);
          dispatchSignal(sig);
    }
}
```

Program sample 7

5-1-3 Mailbox

Every task in the generic software framework has a Mailbox to store signals. The mailbox provides interfaces to push and retrieve signals. We use the “Strategy” pattern [17] to design and implement the *Mailbox* class. Fig. 13 shows the strategy pattern consists of a *Mailbox* class and a set of *Oueue* strategy classes:



```
NucleusQueue::push(Signal sig)
{
   NU_Send_To_Mailbox( &mailbox, sig, 0);
}
```

```
Win32Queue::push(Signal sig)
{
   lock.enter();
   q.push(sig);
   lock.leave();
}
```

Fig. 13 Mailbox design pattern based on the Strategy pattern

The `Mailbox` (*Context*) composites a reference to a `Queue` object. The `Queue` is an abstract class (*Strategy*) which defines the common interface to all strategies. The Win32Queue and NucleusQueue are subclasses of `Queue` (*Concrete Strategy*) that are implemented for different OS. Sub-classes of Queue have similar behaviors and provide various implementations strategies for Mailbox. This design makes it easy to port the GKI Mailbox on different OS.

The *Mailbox* class composites a queue and delegate the duty of storing signals to its queue. It provides methods to push, to fetch and to pop signals. The Mailbox provides a "wait" method to prevent from pooling its queue, which can greatly save lots of computing time. The Mailbox maintains atomic-access mechanism to access its queue.

Here we give examples to explain how the Mailbox is used to store and retrieve signals. Fig. 14 illustrates the sequence of sending a signal to a task. The receiver task pushes the signal into its mailbox. The mailbox of the receiver task delegates this duty to the internal queue object.

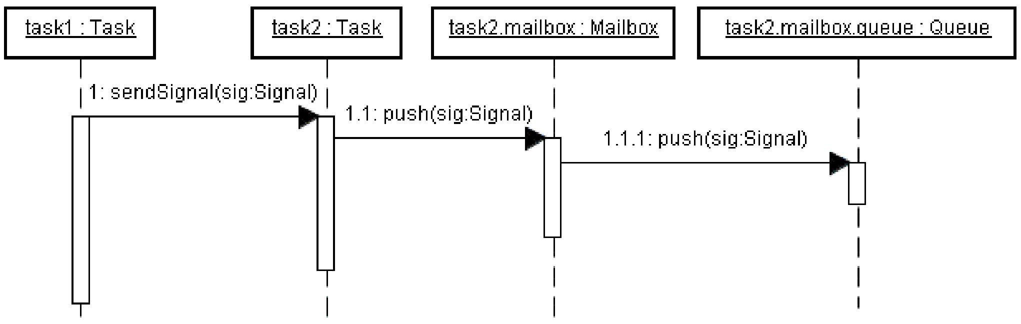


Fig. 14 Sequence diagram: task1 send a signal to task2

Fig. 15 depicts the sequence of fetching a signal from a mailbox. The task2 is waiting for a signal after it calls the `wait` method. When a signal is available, the task2 fetch the signal by calling the `front` method and disposes this signal by calling `pop` method.

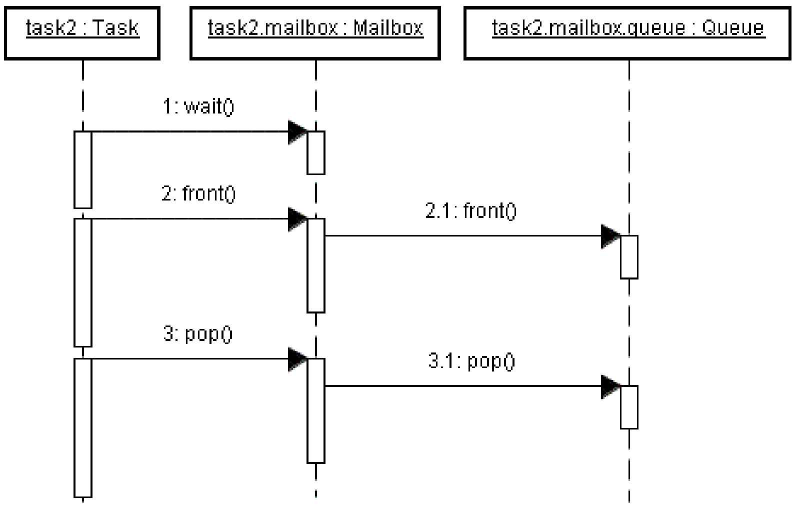
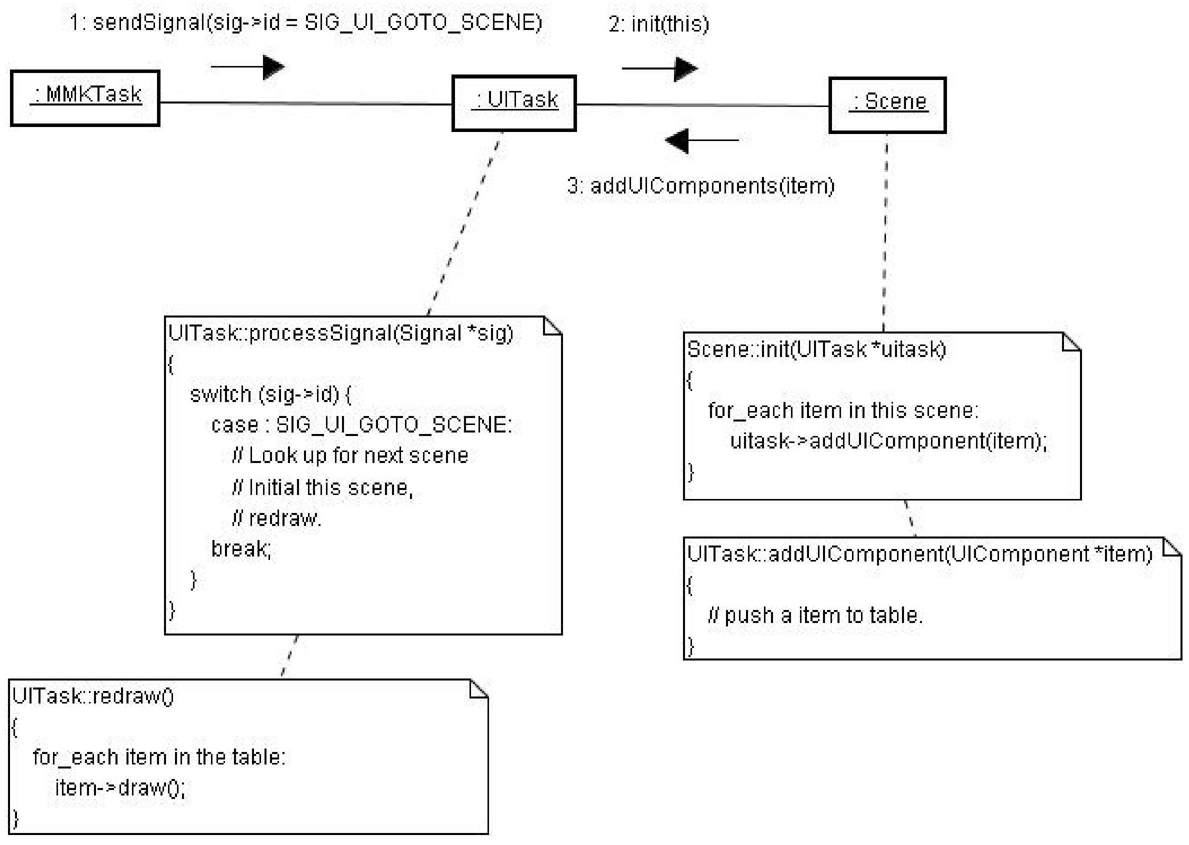


Fig. 15 Sequence diagram: Task2 fetch a signal from its mailbox

5-2 UI task

The UI task maintains a set of scenes that was generated from the visual-based UI authoring system. Each scene is composed with icons, buttons and pictures. The MMI kernel task sends signals to UI task to trigger the changeover of scenes.

The UI task applies the State pattern to maintain the transition of scenes, as shown in Fig. 16.



```
UITask::processSignal(Signal *sig)
{
   switch (sig->id) {
      case : SIG_UI_GOTO_SCENE:
         // Look up for next scene
         // Initial this scene,
         // redraw.
      break;
   }
}
```

```
Scene::init(UITask *uitask)
{
   for_each item in this scene:
      uitask->addUIComponent(item);
}
```

```
UITask::addUIComponent(UIComponent *item)
{
   // push a item to table.
}
```

```
UITask::redraw()
{
   for_each item in the table:
      item->draw();
}
```

Fig. 16 Collaboration diagram: UI task

The program generator translates the visual UI requirement into code snips for UI task. We will illustrate the implementation of UI task by the following pseudo code:

```
UITask::UITask()
{
    // the program generator inserts the UI scenes:
    entry.first = "Scene223";
    entry.second = Scene223::Instance;
    mSceneMap.insert( entry );
    // ...(more UI scenes)

    // The program generator inserts the control scenes:
    entry.first = "IncommingCallScene";
    entry.second = IncommingCallScene::Instance;
    mSceneMap.insert( entry );
    // ...(more control scenes)
}
```

Program sample 8

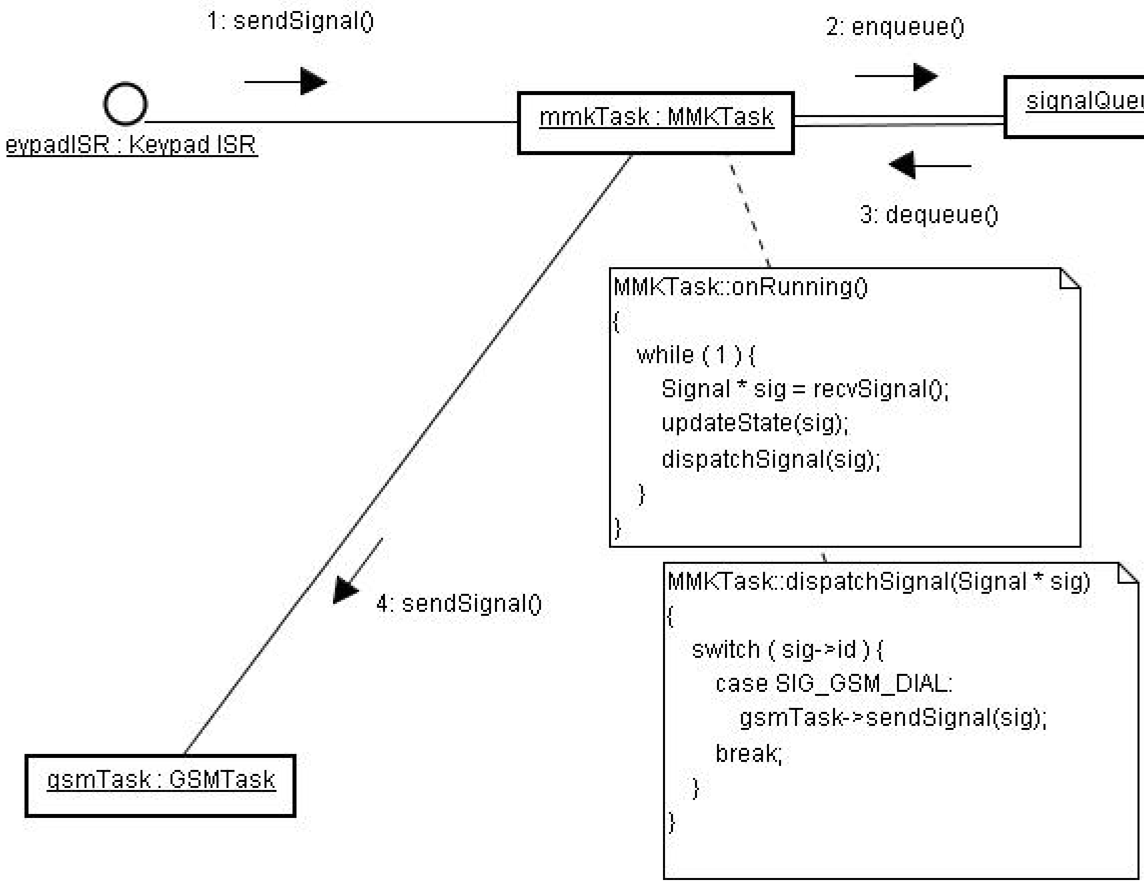
The program generator inserts the MMI scenes and the control scenes into the program of the UI task. The UI task will execute these code snips at run time. When the UI task receives a signal with the identification set to SIG_UI_GOTOSCENE, it handles this signal by 1: look up for next scene; 2: update the current scene; and 3: redraw the panel for the current scene. Here we give the pseudo code to explain how the UI task handles the SIG_UI_GOTOSCENE signal:

```
void UITask::processSignal(Signal * sig)
{
    switch(sig->id) {
        case SIG_UI_GOTOSCENE:
            // find the next scene in the lookup table
            // update the current scene
            // redraw the current scene
            break;
    }
}
```

Program sample 9

5-3 MMI kernel task

The MMI kernel task is an “event listener” and “event dispatcher” in the generic software framework. It handles events by dispatching these events to other task. This is especially important for a user responsive system. When an event requires a long time to be handled, the MMI system can still keep the event highly responsive. User may want to know the progress of event or cancel the event that was launched before. With the responsive listener, the system can react to external events quickly. The design of MMI kernel task is based on the "Active Object" pattern [18], which is shown in Fig. 17:



```
MMKTask::onRunning()
{
  while ( 1 ) {
    Signal * sig = recvSignal();
    updateState(sig);
    dispatchSignal(sig);
  }
}
```

```
MMKTask::dispatchSignal(Signal * sig)
{
  switch ( sig->id ) {
    case SIG_GSM_DIAL:
      gsmTask->sendSignal(sig);
    break;
  }
}
```

Fig. 17 Collaboration diagram: MMI kernel task

The MMI kernel task listens for external events and reacts to them. It maintains its states and reacts to events according to the current status. When a signal (as event) is fetched from the signal queue, the MMI kernel task processes this signal in the following order:

1. Recognize the type of the signal.
2. Update the current state with this signal.
3. Look up for the event handler.
4. Dispatch this signal to the dedicated task to handle this signal.

Fig. 18 is the state diagram that represents the internal states of MMI kernel task for handling the events in GSM sub-system:

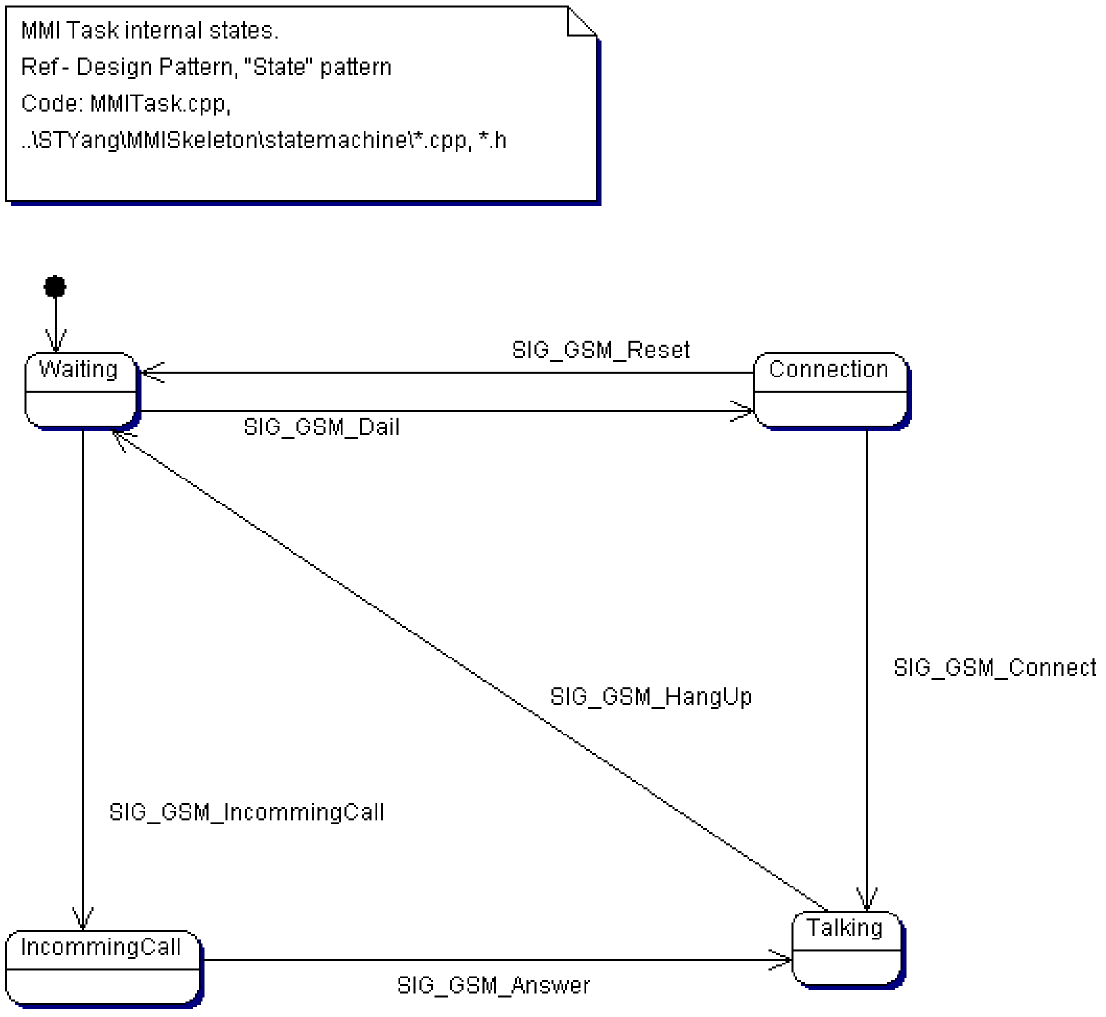


Fig. 18 Internal states of MMI kernel task

5-4 GSM task

The GSM sub-system handles all communication events and provides the mobile communication services such as to dial a phone, to hang up a call, to indicate an incoming call, and to accept a call, and so on.

We model the GSM sub-system as a modem, and design the GSM task to handle the GSM sub-system. With the AT command interface [8], the GSM task can control the GSM sub-system and simulates the GSM communication features.

The GSM task waits for incoming signals from MMI, decides the action to be taken, and sends the AT command to GSM module. The GSM task provides three kinds of GSM communication services:

1. Originate a call
2. Answer a call
3. Hang up a call

Each service is invoked by a corresponding signal, as below:

1. SIG_GSM_DAIL
2. SIG_GSM_ANSWER
3. SIG_GSM_HANGUP

In addition, the corresponding functions to perform these services are listed below respectively:

1. `dial()`
2. `answer()`
3. `hangUp()`

The GSM task inherits from the Task class and overwrites the `processSignal` method. In `processSignal`, we pair the corresponding device functions with signals. Here we use a switch-case statement to discriminate the action needed to handle these signals. In addition, the pseudo-code of the GSM task is list as below:

```
void GSMTask::processSignal(Signal * msg)
{
    switch (sig->id) {
    case SIG_GSM_DAIL :
        dial();
        break;
    case SIG_GSM_ANSWER :
        answer();
        break;
    case SIG_GSM_HANGUP :
        hangUp();
        break;
    }
}
```

Program sample 10

Here we give an example to explain how the MMI kernel task requests the GSM task to make a phone call. When the MMI kernel task decides to make a phone call, it sends a signal to GSM task to perform this service. The sending signal contains the phone number to dial and the signal identification is set to SIG_GSM_DIAL. When the GSM task receives this signal, it executes this request by sending an AT command to the GSM module. Fig. 19 illustrates the concept of this dialing process:

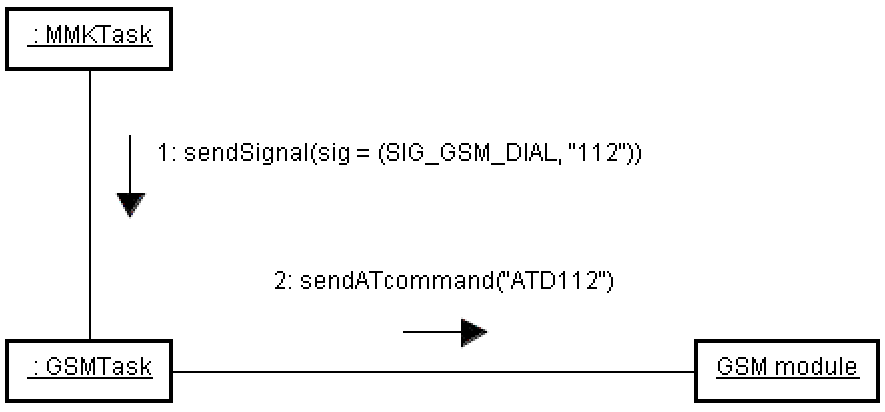

: MMKTask
1: sendSignal(sig = (SIG_GSM_DIAL, "112"))
2: sendATcommand("ATD112")
: GSMTask
GSM module

Fig. 19 Collaboration diagram: Making a phone call

5-5 DSC task

The DSC task provides functions of digital camera. When the user requests the DSC module to take a snapshot The MMI kernel task processes the request by sending a signal to DSC task. The DSC task processes the request by calling corresponding drivers to perform the service. The detail design of DSC task and the device drivers can be found in [12].

Here we give an example to elaborate how the MMI kernel task and the DSC task cooperate to perform a snapshot. When the MMI kernel task decides to make a snapshot, it creates a signal, set the identification field to SIG_DSC_SNAPSHOT, and send to DSC task. When DSC task receives this signal, it executes the corresponding driver function to drive the DSC module to make a snapshot. Fig. 20 shows the collaboration diagram of taking a snap shot.

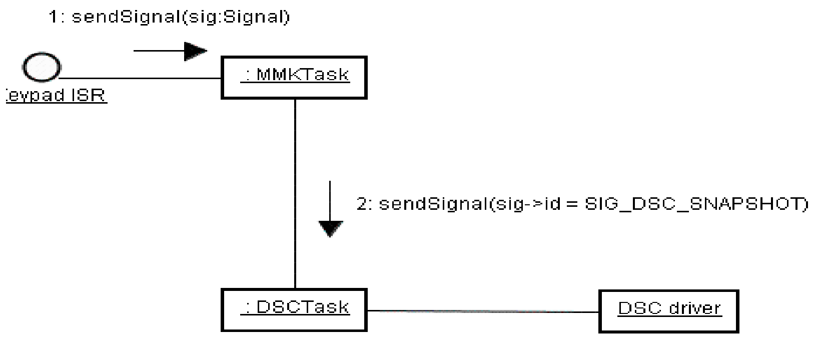

1: sendSignal(sig:Signal)
: MMKTask
eypad ISR
2: sendSignal(sig->id = SIG_DSC_SNAPSHOT)
: DSCTask
DSC driver

Fig. 20 Collaboration diagram: Take a snap shot

Here we explain the implementation of the DSC task by giving the following pseudo code:

```
void DSCTask::processSignal(Signal * msg) {
    switch ( msg->sid ){
        case SIG_DSC_SNAPSHOT:
        // perform snapshot
        break;
    }
}
```

Program sample 11

5-6 Keypad ISR

The keypad ISR sends signal to MMI kernel task on key press events.

The processor of the handset device executes the Keypad ISR on the key press interrupt. Each time the key is pressed, the processor is triggered by a hardware interrupt. Then the processor executes the Keypad ISR to send a signal to MMI kernel task.

The MMI kernel task need to distinguish two kinds of keypad events: "press" or "long press". Consider the '**cancel**' key of a handset. In most case, this key is designed to have two meanings: one is for canceling the current operation, and the other is for powering off the handset. Therefore, the Keypad ISR has to distinguish the difference between the normal "press" and the "long press", and send different signal to MMI kernel task. Both types of signals have different meanings, and the way to handle these two signals depending on the design of MMI scenarios. The Keypad ISR will keep the states and report the key pressed events according to the current state. The states diagram of the keypad ISR is described in Fig. 21:

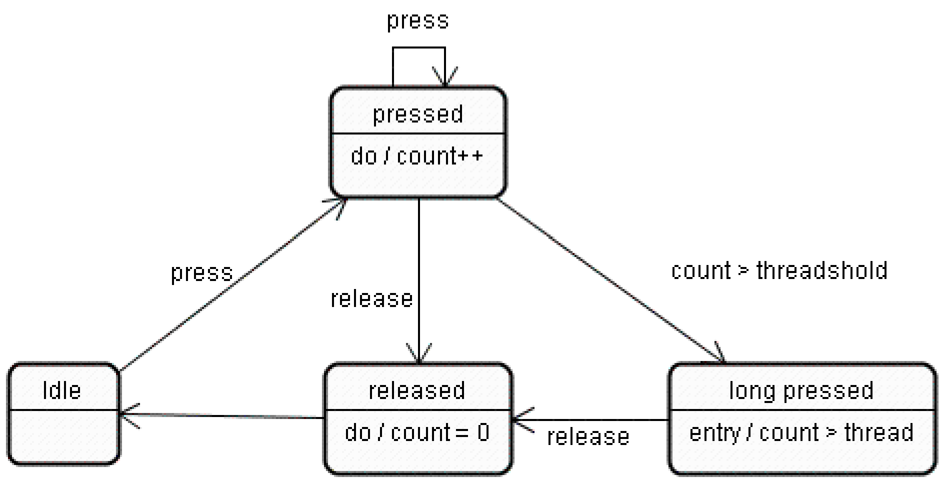


Fig. 21 States diagram of keypad ISR

The following pseudo code explains the algorithm of the keypad ISR:

```
void KeypadISR(void)
{
    // scan the keypad to get the pressed code
    int key = hw_scankey();

    if ( !bLongPress  &&  (0 == iKeyPress) ) {
        // perform key press event
        KeypadSignal *sig = new KeypadSignal;
        sig->sid = SIG_KEY_PRESS;
        sig->mKey = key;
        MMITask->sendSignal(sig);
    }

    iKeyPress++;

    if ( LONG_PRESS_THRESHOLD == iKeyPress ) {
        // perform long press event
        bLongPress = true;
        iKeyPress = 0;
        KeypadSignal *sig = new KeypadSignal;
        sig->sid = SIG_KEY_LONG_PRESS;
        sig->mKey = key;
        MMITask->sendSignal(sig);
    }
}
```

Program sample 12

5-7 Display API

The Display API is a set of functions that draw images on panel. A complete study of the Display API is beyond the scope of this thesis. In this study, we use the Borland VCL [19] to emulate the Display API. A detailed treatment on this subject can be found in [20].

Chapter 6

Simulation and Application Examples

In this chapter, we explain the run time behavior of the generic software framework. In order to verify the generic software framework and the user look and feel that generated from the authoring system, we implemented a software simulator that can be executed in PC environment.

6-1 Introduction of the simulator

The simulator helps us to verify the design of the MMI scenarios. It can accept key press, display the operation status, and execute the corresponding functions. We show the look and feel of the simulator in Fig. 22:

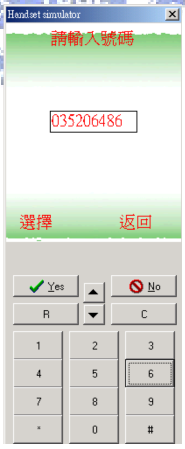


Fig. 22 **The look and feel of the simulator**

We can originate a call or accept a call on the simulator. When we press the buttons on the simulator, the UI task will display a series of numbers on the panel of the simulator.

6-2 The design and implementation of the simulator

In this section, we will make a tutorial on the design and implementation of the simulator. The simulator has several components that will be elaborated in 6-2-1. We collect these software components and compile to an executable program. The simulator is executed on PC and it controls the external devices, the DSC module and the GSM module, via the data cable.

6-2-1 The software architecture of the simulator

The software architecture of the simulator includes *GKI class library* that was specified to Win32 OS platform; a *software design framework* that was specified to simulation environment; a set of *MMI scenarios* that was generated by the visual-based UI authoring system; and a *graphic user interface (GUI)* to stand for the keypad and the panel. The software architecture of the simulator is shown as Fig. 23.

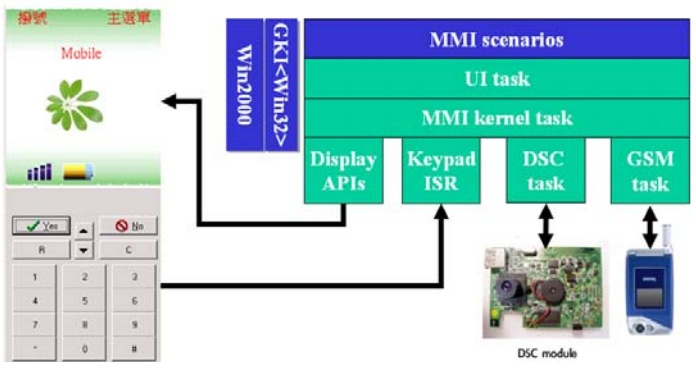


Fig. 23 The software architecture of the simulator

The simulator combines a graphic user interface (GUI) with a software design framework. On the left hand side of Fig. 23 is the GUI of the simulator. The GUI has a panel on the top and a keypad on the button. The simulator displays UI to the panel and handles user input from the keypad. When user presses the keypad, the Keypad ISR reports the key-pressed events to MMI kernel task, and the UI task represent the MMI scenarios on the panel. Here we use a real handset to stand for the GSM sub-system and a DSC evaluation board to stand for a DSC hardware device.

6-2-2 The design and implementation of the simulator

We create a software design framework from the generic software framework to fulfill the requirement of simulation. The generic software framework is specialized to Win32 OS platform and hardware devices. Fig. 24 illustrates the creation of the software design framework.

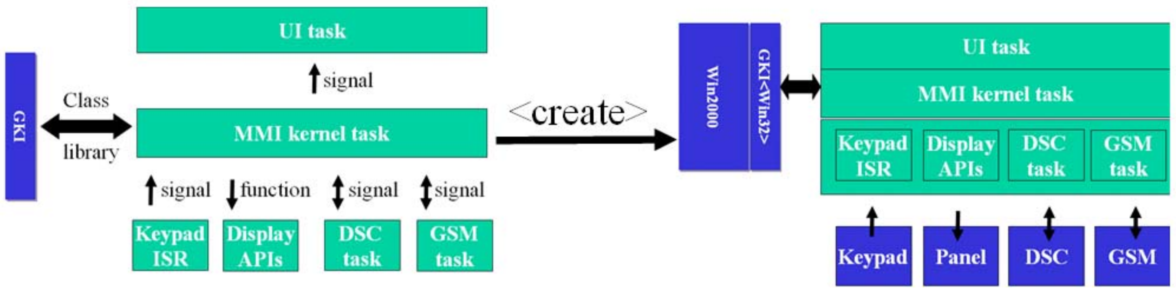


Fig. 24 Create a software design framework for simulator

The *GKI* of the software design framework is specific to Win32 platform. We implement the GKI class library for Win32 OS platform. The methods for porting GKI class library are mentioned at 5-1 Design and Implementation of Generic Kernel Interface (GKI).

The *keypad ISR* of the simulator is implemented as an event handler of the GUI. When user presses the keypad, the event handler is invoked to report this event to MMI kernel task.

In this thesis, we do not implement the *Display API* but use the Borland Visual Component Library (VCL) to perform this service instead. By the help of VCL, each actor in the MMI scenarios has a method to draw itself on the panel.

The *GSM task* interacts with the GSM sub-system via AT command interface. A serial port is opened to transact the AT commands and response between software design framework and GSM sub-system.

The *DSC task* and the DSC evaluation board are connected by a USB cable. The DSC task sends commands to DSC module via the USB data cable. The DSC module processes commands and response the execution result to DSC task.

6-3 Application examples

The program generator glues the MMI scenarios with the software design framework. Fig. 25 depicts the process flow of program generation:

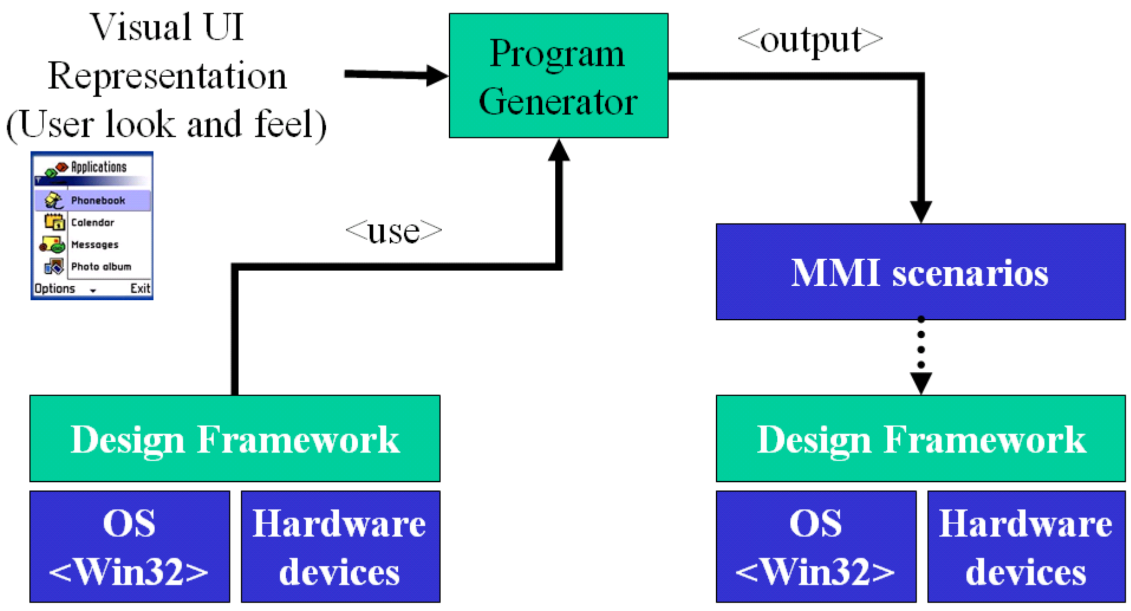


Fig. 25 The program generator combines the user look and feel with the design software framework

Here we explain how the user look and feel is combined with the application function.

The UI designer uses the visual-based authoring system to edit the UI requirement and produces user look and feel. The UI designer uses the function binder to combine the application functions with the user look and feel. Then the program generator translates the relationship between application functions and user look and feel into code snips, and adds these code snips to the program of UI task. After the program generation is completed, the programmer compiles the program to a software application for handset devices.

When the handset application is running, the MMI kernel task accepts external events and dispatches event to corresponding task. When the MMI kernel task receives a signal, it will look up for the next scene in the MMI scenarios, update the current scene and send signals to UI task to update the current scene. Then the UI task will redraw the panel to represent the current scene. The MMI kernel will also send signals to request the DSC task and/or GSM task to perform application services. The DSC task and/or the GSM task will handle the request signal by executing the corresponding application functions.

We will demo three examples in the following sub-sections. Each demo explains the runtime signal flow of the software framework .

6-2-1 Making a phone call

The Fig. 26 shows the signal flow of dialing a call. When user press the button of the simulator, the keypad ISR is triggered (see Fig. 26 step 1) to report the key press event to MMI kernel task (step 2). The MMI kernel task handles this event by triggering the UI task to update the current scene (step 3). After user press ten numbers and press the "yes" key, the simulator will make a phone call by sending a signal to GSM task to request a dial service (step 4). The GSM task handles this signal by sending an AT command to the external GSM module (step 5).

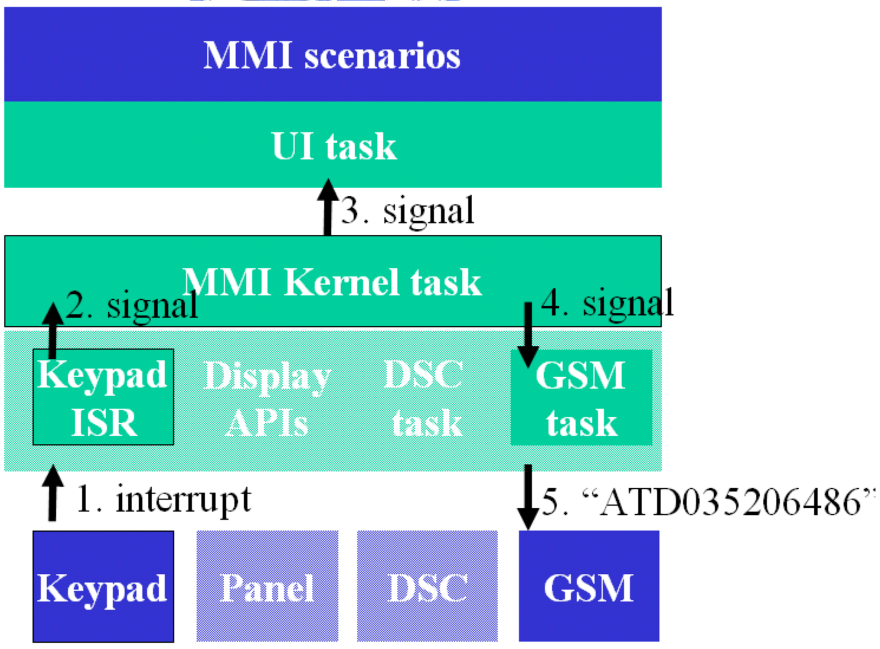


Fig. 26 The signal flow of dialing a call

6-2-2 Incoming call

We use Fig. 27 to illustrate the signal flow of an incoming call in the software framework. When the GSM sub-system receives a call, it sends an AT command “RING” to indicate the GSM task (step 1). The GSM task processes this indication by sending a signal to MMI kernel task (step 2). The MMI kernel task process this signal by updating the current state and dispatches this signal to UI task to update the current scene (step 3).

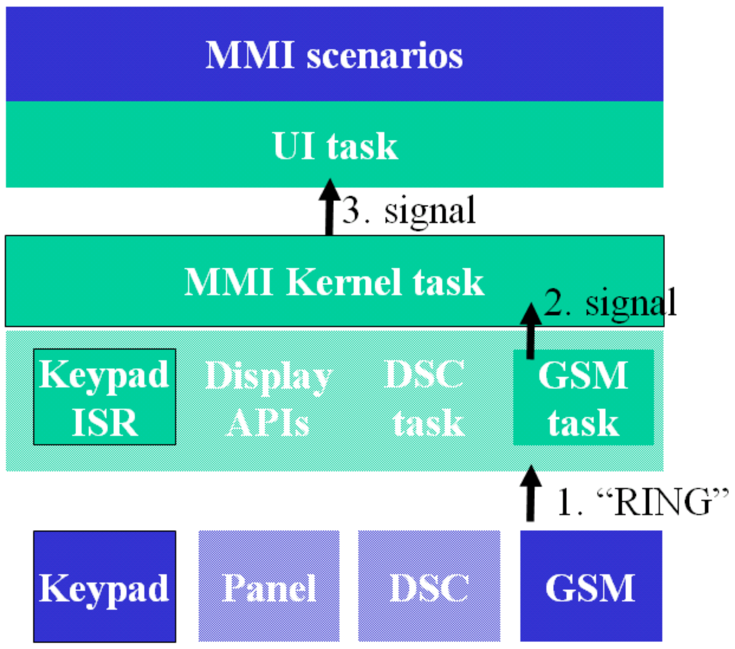


Fig. 27 The signal flow of incoming call

6-2-3 Accept a call

We illustrate the signal flow for accepting a phone call in Fig. 28. When user presses keypad to accept the incoming call, a hardware interrupt is triggered to execute the keypad ISR (step 1). The keypad ISR reports this event to MMI kernel task (step 2). The MMI kernel task dispatches this signal to UI task (step 3) and GSM task (step 4). The GSM task process this event by sending an AT command "ATA" to GSM sub-system to accept this call.

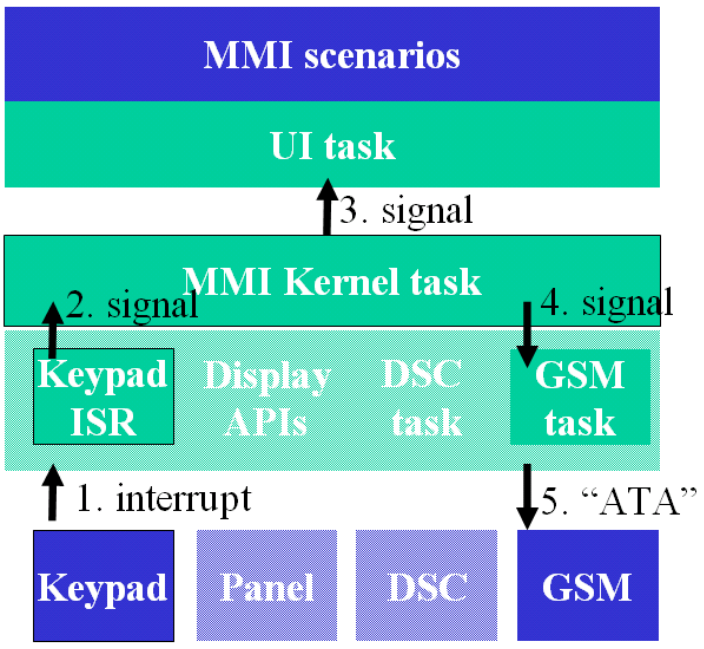


Fig. 28 The signal flow of accepting a call

Chapter 7

Conclusions and Future Work

The development process for creating MMI is a time-consuming task. The programmers take the main role to develop the software. The visualize-programming tool can help programmers to create MMI quickly. This methodology relies on the prerequisite of a software framework for handset devices. This framework has responsibility to provide a platform for MMI scenarios that was generated by authoring tool. It provides a platform to represent the MMI scenario. The framework also encapsulates the implementation details of OS and hardware devices, and provides a stable interface for software application.

A generic software framework for the handset device is proposed in this thesis study. The generic software framework is a template of software architecture for handset devices. When a specific target platform requires a software design framework, programmers can instantiate one from the generic software framework. The generated software framework provides an OS-independent and hardware-independent platform for the MMI requirement that authored by Visual UI Authoring system. The program generator produces the target program of handset device using the generic software framework as system architecture.

It has some efforts to instantiate a software framework from the generic software framework. The hotspots of the generic software framework include the GKI and the tasks that control the hardware devices. Programmers implement these functions depend on each version of OS and different type of device drivers.

In this thesis study, we do not have complete study on the topic of the display API. According to the J2ME MIDP, it defines the model of the user interface for the handset panel. We may have a further study in the MIDP and try to use this approach to create an approach to implement the display API.

In addition, we do not analysis the runtime performance of the software framework, which is an important issue for a handset device. We implement the simulator to make the conformance analysis to proof our approach, and we can apply our approach to a real handset to prove the runtime performance.

The generic kernel interface adapts the application and the operating system. The performance issue is highly related with the RTOS, and we can try to port the GKI to another OS platform to make certain of this approach.

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