Bluetooth Gravity Mouse

An exploration of socket programming and UI design from QT and QML
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Design Overview

High-level Description

The Bluetooth Gravity Mouse is a fully-functional Human Interface Device that allows the users to control their PCs using their smartphone without internet. Users control the cursor on their PC by tilting their smartphones, and simulate mouse clicking of both left button and right button by tapping the screen. The smartphone acts as a bluetooth server while the PC acts as a bluetooth client, and users are able to pause and resume the service without closing and reopening the application. A core feature of this project is the fluid interface design. It not only provides the basic functionalities but also brings splendid user experience.

Original Design Concept

Looking back to our childhood, we are still able to remember the excitement when we first got to play games like Asphalt 5 where we could tilt our devices to control the race car. Are we able to apply the same concept to Human Interface Devices, or more specifically cursor control? Could we control the cursor just like we control the racecar?

Previous Works Expansion

There have been several attempts from developers to make smartphones as HID Mouse, yet all of these apps use a local area network which requires a local router, none of which make use of on-device sensors on smartphones, and more importantly, The interface designs in these projects are sub par. This project, however, did not use a single line of code from the internet, and everything was started from scratch.

Preliminary Design Verification

All client-side testing is conducted on Windows 10 19045 using MSVC2019 from x86-64 architecture, and all server-side testing is conducted on ARM64 architecture.

Client Side

Communication Protocol Testing

Finalizing the software framework selection and communication protocol, a simple program is written to test if the framework is able to correctly identify and gain access to the bluetooth module on the local device. QBluetoothDeviceDiscoveryAgent class is used to provide a simple nearby bluetooth device scanning using the on-device bluetooth module. Turning the logging filter for bluetooth. QBluetoothDeviceDiscoveryAgent is not to be used in the final application, because this is only for testing the bluetooth module. Users are responsible to identify MAC addresses on both devices, as both Windows and Android operating systems do not provide a way to access the host MAC address programmatically.

```
auto deviceDiscoveryAgent = new QBluetoothDeviceDiscoveryAgent(this);
QObject::connect(deviceDiscoveryAgent, &QBluetoothDeviceDiscoveryAgent::deviceDiscovered, this,
[this](const QBluetoothDeviceInfo & info) {
   qInfo() << ("agent device discovered " + info.address().toString() + " " + info.name());
});
QObject::connect(deviceDiscoveryAgent, &QBluetoothDeviceDiscoveryAgent::finished, this, [this]() {
   qInfo() << disp("agent finished " );
});
QObject::connect(deviceDiscoveryAgent,
static_cast<void(QBluetoothDeviceDiscoveryAgent::*)(QBluetoothDeviceDiscoveryAgent::Error)>(&QBluetoothD
eviceDiscoveryAgent::error), this, [this](QBluetoothServiceDiscoveryAgent::Error error) {
   qInfo() << disp("agent error " +
QString::fromUtf8(QMetaEnum::fromType<QBluetoothDeviceDiscoveryAgent::Error>().valueToKey(error)));
});
QLoggingCategory::setFilterRules(QStringLiteral("qt.bluetooth* = true"));
deviceDiscoverAgent->start();
```

Running this code yields no error on Android devices, yet some unexpected behaviors occurred while testing on Windows devices which are later resolved. It turned out to be a compiler issue. This issue is discussed in more detail under the Design Testing section.

Cursor Moving Functional Testing

The QCursor class provides functionalities to let users gain direct control of cursor position.

```
QCursor cursor = QCursor();
cursor.setPos(0, 0);
```

The setPos() method successfully sets the cursor to the top left position of the main screen.

Cursor Clicking Functional Testing

The QCursor class mentioned above is solely responsible for moving the cursor, yet it does not provide a way to simulate the mouse clicking event. Because of this, relying on the Windows API is the only viable option.

The mouse_event() method defined in winuser.h provides a way to simulate both left-button and right-button clicking events by setting corresponding flags from the first argument.

```
#if defined(Q_OS_WINDOWS)
#pragma comment(lib, "User32.lib")
        mouse_event(MOUSEEVENTF_ABSOLUTE | MOUSEEVENTF_LEFTDOWN | MOUSEEVENTF_LEFTUP, 1, 1, 0, 0);
        mouse_event(MOUSEEVENTF_ABSOLUTE | MOUSEEVENTF_RIGHTDOWN | MOUSEEVENTF_RIGHTUP, 1, 1, 0, 0);
#endif
```

The function call is guarded by the Q_OS_WINDOWS macro so that this method is not accidentally called on the Android (server) side, and User32.lib import should be explicitly marked to link the library to the executable.

When running on Windows, it successfully simulated mouse left-clicking and right-clicking events at the current cursor position.

Receiving Socket Testing

Before testing for the service-broadcasting server, it is important to construct a socket to receive information that is sent from the server. This can be achieved by using the QBluetoothSocket class.

```
auto socket = new QBluetoothSocket(QBluetoothServiceInfo::RfcommProtocol, this);
QObject::connect(socket, &QBluetoothSocket::disconnected, this, [this]() {
        qInfo("socket disconnected"+ "");
});
QObject::connect(socket, &QBluetoothSocket::connected, this, [this]() {
        qInfo("socket connected to"+ socket->peerAddress().toString(), false);
});
QObject::connect(socket,
        static_cast
<void(QBluetoothSocket::*)(QBluetoothSocket::SocketError)>(&QBluetoothSocket::error),
        this, [this](QBluetoothSocket::SocketError error) {
              qInfo("socket error occured"+
              QString::fromUtf8(QMetaEnum::fromType<QBluetoothSocket::SocketError>()
              .valueToKey(error)));
});
QObject::connect(socket, &QBluetoothSocket::stateChanged, this,
                                  [this](QBluetoothSocket::SocketState state) {
              qInfo("socket state changed"+
              QString::fromUtf8(QMetaEnum::fromType<QBluetoothSocket::SocketState>()
              .valueToKey(state)));
});
```

```
QObject::connect(socket, &QBluetoothSocket::readyRead, this, [this]() {
        QString dataRead = QString::fromUtf8(socket->readAll());
        qInfo("socket read" + dataRead);
});
socket->connectToService(QBluetoothAddress("9C:BC:F0:CF:32:AF"), QBluetoothUuid::SerialPort);
```

The socket is now able to connect to the device with a specified address (9C:BC:F0:CF:32:AF in this case) and to read any information sent from that address. This code is not executed until the service-broadcasting Bluetooth server and its corresponding socket from the server side has been initialized. More details can be found under Bluetooth Service Broadcasting subsection under Server Side section.

Server Side

Tilt Sensor Reading Testing

The QT Sensors API provides an easy way to access the current horizontal and vertical values of device tilting angles.

```
auto tileSensor = new QTiltSensor(this);
QObject::connect(tileSensor, &QTiltSensor::readingChanged, this, [this]() {
        qInfo()<< "x" << tileSensor->reading()->xRotation();
        qInfo()<< "y" << tileSensor->reading()->yRotation();
});
QObject::connect(tileSensor, &QTiltSensor::sensorError, this, [this](int error) {
        qInfo(("tilt sensor error"+ "code " + QString::number(error));
});
tileSensor->start();
```

Although the sensor should not be used on the PC (client) side, it is not necessary to guard the method, as calling this API from client side, unlike calling Windows API methods from Android, will not yield exceptions and will just not trigger readingChanged() signal. After the code above is executed, a real-time monitoring of tilting angles is printed in the debugging console.

Broadcastor Service & Transmitting Socket Testing

The server will broadcast a bluetooth signal by using QBluetoothService, and listens to incoming socket connections of type QBluetoothSocket.

```
auto server = new QBluetoothServer(QBluetoothServiceInfo::Protocol::RfcommProtocol, this);
QBluetoothSocket* socket = nullptr;
QObject::connect(server,
static_cast<void(QBluetoothServer::*)(QBluetoothServer::Error)>(&QBluetoothServer::error), this,
[this](QBluetoothServer::Error error) {
        qInfo("server error occured"+ QString::fromUtf8(QMetaEnum::fromType<QBluetoothServer::Error>()
        .valueToKey(error)));
```

```
});
QObject::connect(server, &QBluetoothServer::newConnection, this, [this]() {
        socket = server->nextPendingConnection();
        qInfo("socket connected to", "code " + socket->peerAddress().toString());
});
auto serviceInfo = server->listen(QBluetoothUuid::SerialPort, "");
if(server && !server.isNull() && server->isListening()) {
        qInfo("service connected to", "port " + QString::number(server->serverPort()));
}
```

Until now, the sockets are ready to be connected. Executing the code above along with the socket and by calling the write() function from the socket on the server's end, a notification can be seen on the client's client.

Design Implementation

Overall System

Instead of using the legacy QWidgets, this project uses Qt Quick 2.0 as the front-end, powered by QML Engine. The back-end business logic is implemented using C++. The project will automatically detect the server and client side and adapt different interfaces without users specifying it.

Communication Protocol

To establish the communication between the smartphone and PC, a unified communication protocol needs to be defined. In this project, classic bluetooth is used. The smartphone (server) broadcasts the service with a specific UUID while the PC (client) listens to the nearby services by filtering out unrelated ones that have different UUID.

Visual Components

The final interface of the project presented to the users consists of multiple reusable visual components plus a non-visual singleton styling component.

The project went over two phases of interface design. The original implementation uses square components inspired by Windows 10 UI accompanied by linear motion transitioning. However, a redesigning process was initiated at the midpoint of the software development cycle, since the original design gives too much of an abstruse feel.

The second interface design is inspired by the new Android 12, circular components with spring-like transitions, and the way how the interface communicates with the users replicates a basic calculator – information flows out of the device from the top through a digital display pane, and subsequently flows into the device though huge buttons.

Figure. Grid-like Layout in Calculator

The Styling Singleton (MyStyle.qml)

To provide a clean and unified look, a singleton styling sheet is declared and loaded as singleton. It serves two functions - scaling and coloring.

Because the software is runned on a wide variety of devices with distinct screen resolutions and DPI settings, and having only a pair of fixed line width and font size would make the software look okay on one device but disproportional on others. The font size, radius, and line width are all directly controlled by a base value, which is overridden when the main application is rendered.

The coloring of the entire application is classified as highlight(900), foreground(600), buffer(300), background(white). All components from the application are composed of different combinations of these four colors.

```
pragma Singleton
import QtQuick 2.15
Item {
        property int baseValue: 10
        readonly property color color_neutral900: "#1A202C"
        readonly property color color_neutral600: "#717D96"
        readonly property color color_neutral300: "#E2E7F0"
        readonly property color color_neutralWhite: "#FFFFFF"
        readonly property double param_fontSize: baseValue
        readonly property double param_largeFontSize: baseValue * 1.5
        readonly property double param_radius: baseValue
        readonly property double param_lineWidth: baseValue * 0.1
}
```

The Single Line 14 Segment Display (MyLineDisplayer.qml)

The digital display is a multi-row display which contains multiple arrays of single-line display:

Figure. Single Line Digital Display

```
Rectangle {
        id: rootRectangle_myLineDisplay
        property string dispText: "!!!NOT!IN!SERVICE!!!"
        color: "transparent"
        implicitHeight: text_backgroundText.paintedHeight
        implicitWidth: 200
        Text {
                id: text_backgroundText
                anchors.fill: parent
                font.family: "DSEG14 Classic"
                font.pixelSize: MyStyle.param_largeFontSize * 4
                horizontalAlignment: Text.AlignHCenter
                verticalAlignment: Text.AlignVCenter
                styleColor: "#ffffff"
                font.letterSpacing: MyStyle.param_lineWidth
                fontSizeMode: Text.Fit
                text: "~~~~~~~~~~~~~~~~~~~~"
                opacity: 0.15
                color: "#ffffff"
        }
        Text {
                id: text_foregroundText
                anchors.fill: parent
                font.family: "DSEG14 Classic"
                font.pixelSize: MyStyle.param_largeFontSize * 4
                horizontalAlignment: Text.AlignHCenter
                verticalAlignment: Text.AlignVCenter
                font.letterSpacing: MyStyle.param_lineWidth
                fontSizeMode: Text.Fit
                text: {
                        let toDisplay = parent.dispText
                        if (toDisplay.length < 20)
                                toDisplay = toDisplay.padEnd(20, '!')
                        else if (toDisplay.length > 20)
                                toDisplay = toDisplay.substring(0, 20)
                        return toDisplay.replace(/\W/g, '!').replace(' ', '!')
                }
                color: MyStyle.color_neutralWhite
        }
}
```

The Multi Line 14 Segment Display (MyDisplayer.qml)

The final display pane is populated using the single-line display using model-view-delegate pattern:

```
Rectangle {
        id: rootRectangle_myDisplay
        implicitHeight: 400
        implicitWidth: 500
        color: MyStyle.color_neutral900
        radius: MyStyle.param_radius
        property int numberOfLines: 5
        property string dispText: "t\ne\ngeeg"
        onDispTextChanged: passDispTextToLines()
        Column {
                id: column_linesOfDisplay
                anchors.fill: parent
                anchors.margins: MyStyle.param_lineWidth * 10
                spacing: MyStyle.param_lineWidth * 10
                clip: true
                Repeater {
                        id: repeater_linesOfDisplay
                        model: numberOfLines
                        delegate: MyLineDisplay {
                                anchors.left: column_linesOfDisplay.left
                                anchors.right: column_linesOfDisplay.right
                                height: (column_linesOfDisplay.height
                                                - (column_linesOfDisplay.spacing
                                                        * (rootRectangle_myDisplay.numberOfLines -
1)))
                                                / rootRectangle_myDisplay.numberOfLines
                        }
                        Component.onCompleted: passDispTextToLines()
                }
        }

        function passDispTextToLines() {
                let splittedDispText = rootRectangle_myDisplay.dispText.split('\n')
                let smallerIndex = Math.min(rootRectangle_myDisplay.numberOfLines,
                                                                        splittedDispText.length)
                for (var i = 0; i < smallerIndex; ++i) {
                        if (repeater_linesOfDisplay.itemAt(i) !== null)
                                repeater_linesOfDisplay.itemAt(i).dispText = i
                                                < splittedDispText.length ? splittedDispText[i] :
"!!!!-!!!!!-!!!!!-!!!"
                }
        }
}
```

Although it is specified in this very specific project to use 2 lines, it is possible to have more than 2 lines, and the height of each line is automatically calculated.

Figure 1. Multi-line Segment Display

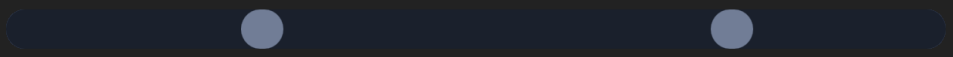
The Readings Observer (MyReadingsObserver.qml)

Another cool component is the reading observer. The positions of the two levers will slide horizontally, and they are the readings of tilt sensors reading data received from the smartphone.

```
Rectangle {
        id: rootRectangle_myReadingsObserver
        implicitHeight: 100
        implicitWidth: 400
        color: MyStyle.color_neutral900
        radius: MyStyle.param_radius
        property double xVal: -0
        property double yVal: -0
        property color readingsColor: MyStyle.color_neutral600
        Rectangle {
                id: rightGauge
                x: {
                        let xMinimum = rootRectangle_myReadingsObserver.x
                                + rootRectangle_myReadingsObserver.width / 2
                        let xMaximum = rootRectangle_myReadingsObserver.x
                                + rootRectangle_myReadingsObserver.width
                                - rootRectangle_myReadingsObserver.radius * 2
                        let xMiddle = (xMaximum + xMinimum) / 2
                        return xMiddle + (xMaximum - xMinimum) / 2 * xVal
                }
                Behavior on x {
                        SpringAnimation {
                                spring: 1
                                damping: 0.2
                        }
                }
                color: readingsColor
                anchors.top: rootRectangle_myReadingsObserver.top
                anchors.bottom: rootRectangle_myReadingsObserver.bottom
                radius: MyStyle.param_radius
                width: MyStyle.param_radius * 2
        }
        Rectangle {
                id: rectangle_leftGauge
                x: {
                        let xMinimum = rootRectangle_myReadingsObserver.x
                        let xMaximum = rootRectangle_myReadingsObserver.x
                                + rootRectangle_myReadingsObserver.width / 2
                                - rootRectangle_myReadingsObserver.radius * 2
                        let xMiddle = (xMaximum + xMinimum) / 2
                        return xMiddle + (xMaximum - xMinimum) / 2 * yVal
```

```
                }
                Behavior on x {
                        SpringAnimation {
                                spring: 1
                                damping: 0.2
                        }
                }
                color: readingsColor
                anchors.top: rootRectangle_myReadingsObserver.top
                anchors.bottom: rootRectangle_myReadingsObserver.bottom
                radius: MyStyle.param_radius
                width: MyStyle.param_radius * 2
        }
}
```

To provide a better visual experience for the users, the movement of two levers follows the spring-like movement, following a pattern of simple harmonic motion.



The Dialer (MyDialer.qml)

The dialer component is the keypad that allows the user to control the software:

```
Rectangle {
        id: rootRectangle_myDialer
        implicitHeight: 500
        implicitWidth: 600
        color: MyStyle.color_neutral900
        radius: MyStyle.param_radius
        property bool isClient: true
        property color buttonsColor: MyStyle.color_neutral600
        property color buttonColor2: MyStyle.color_neutral800
        property color buttonLabelColor: MyStyle.color_neutral300
        signal buttonClicked(string buttonText)
        Grid {
                id: grid_buttons
                rows: isClient ? 4 : 1
                columns: isClient ? 4 : 1
                anchors.top: parent.top
                anchors.left: parent.left
                anchors.right: parent.right
                height: parent.height * 0.7
                anchors.margins: MyStyle.param_lineWidth * 10
                spacing: MyStyle.param_lineWidth * 10
                Repeater {
                        id: repeater_buttons
                        model: isClient ? ["0", "1", "2", "3", "4", "5", "6", "7", "8", "9", "A", "B",
"C", "D", "E", "F"] : ["CL"]
                        delegate: Rectangle {
                                width: (grid_buttons.width - (grid_buttons.columns - 1)
                                                * grid_buttons.spacing) / grid_buttons.columns
```

```
                                height: (grid_buttons.height - (grid_buttons.rows - 1)
                                         * grid_buttons.spacing) / grid_buttons.rows
                                radius: mouseArea_button.pressed ? MyStyle.param_radius * 4 :
MyStyle.param_radius
                                Behavior on radius {
                                        SpringAnimation {
                                                spring: 5
                                                damping: 500
                                        }
                                }

                                color: mouseArea_button.pressed ? buttonsColor : buttonColor2
                                Behavior on color {
                                        ColorAnimation {
                                                duration: 200
                                        }
                                }

                                Text {
                                        anchors.fill: parent
                                        anchors.margins: mouseArea_button.pressed ?
MyStyle.param_lineWidth

                                        * 10 : MyStyle.param_lineWidth * 5
                                        Behavior on anchors.margins {
                                                SpringAnimation {
                                                        spring: 5
                                                        damping: 500
                                                }
                                        }
                                        font.family: "STHeiti TC"
                                        font.pixelSize: MyStyle.param_largeFontSize * 10
                                        horizontalAlignment: Text.AlignHCenter
                                        verticalAlignment: Text.AlignVCenter
                                        fontSizeMode: Text.Fit
                                        id: text_buttonLabel
                                        visible: isClient
                                        color: buttonLabelColor
                                        text: modelData
                                }
                                MouseArea {
                                        id: mouseArea_button
                                        anchors.fill: parent
                                        onClicked: {
                                                buttonClicked(modelData)
                                        }

                                        onPressAndHold: {
                                                if (modelData === "CL")
                                                        buttonClicked("HO")
                                        }
                                }
                        }
                }
        }
        Grid {
                rows: 1
                columns: isClient ? 3 : 2
                id: grid_bottomButtons
```

```
                anchors.top: grid_buttons.bottom
                anchors.left: parent.left
                anchors.right: parent.right
                anchors.bottom: parent.bottom
                anchors.margins: MyStyle.param_lineWidth * 10
                spacing: MyStyle.param_lineWidth * 10
                Repeater {

                        id: repeater_bottomButtons
                        model: isClient ? ["确认/OK", "地址/AD", "开关/PO"] : ["校正/CA", "开关/PO"]
                        delegate: Rectangle {
                                width: (grid_bottomButtons.width - (grid_bottomButtons.columns - 1)
                                                * grid_bottomButtons.spacing) /
grid_bottomButtons.columns
                                height: (grid_bottomButtons.height - (grid_bottomButtons.rows - 1)
                                                 * grid_bottomButtons.spacing) /
grid_bottomButtons.rows
                                radius: mouseArea_buttomButton.pressed ? MyStyle.param_radius

                 * 4 : MyStyle.param_radius
                                Behavior on radius {
                                        SpringAnimation {
                                                spring: 5
                                                damping: 500
                                        }
                                }

                                color: mouseArea_buttomButton.pressed ? buttonsColor : buttonColor2
                                Behavior on color {
                                        ColorAnimation {
                                                duration: 200
                                        }
                                }

                                Text {
                                        anchors.fill: parent
                                        anchors.margins: mouseArea_buttomButton.pressed ?
MyStyle.param_lineWidth * 30 : MyStyle.param_lineWidth * 10
                                        Behavior on anchors.margins {
                                                SpringAnimation {
                                                        spring: 5
                                                        damping: 500
                                                }
                                        }
                                        font.family: "STHeiti TC"
                                        font.pixelSize: MyStyle.param_largeFontSize * 10
                                        horizontalAlignment: Text.AlignHCenter
                                        verticalAlignment: Text.AlignVCenter
                                        fontSizeMode: Text.Fit
                                        id: text_buttomButtonLabel
                                        color: buttonLabelColor
                                        text: modelData
                                }
                                MouseArea {
                                        id: mouseArea_buttomButton
                                        anchors.fill: parent
                                        onClicked: buttonClicked(modelData.split('/')[1])
                                }
                        }
```

```
                }
        }
}
```

The cool thing about this component is it will automatically detect if the device software is running on is a client or a server, and it will dynamically change its layout to properly describe the kinds of input.

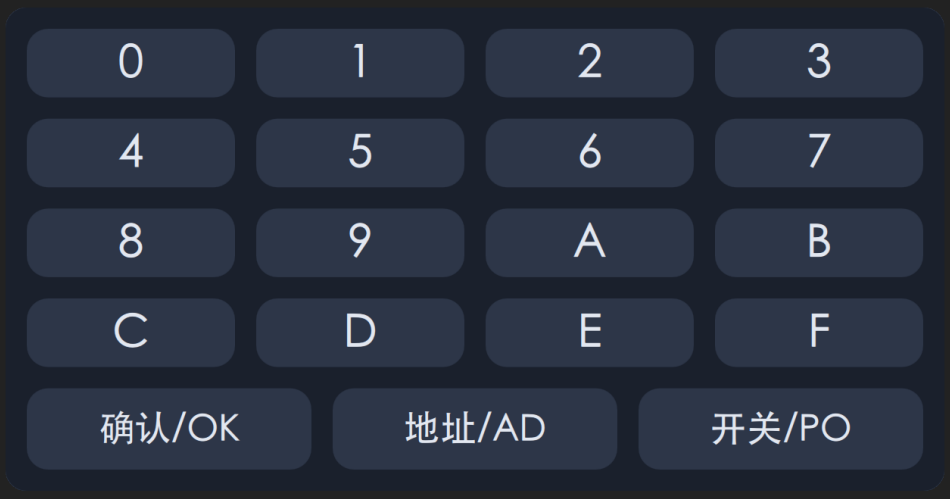


Figure. Dialer Pane on Client Side

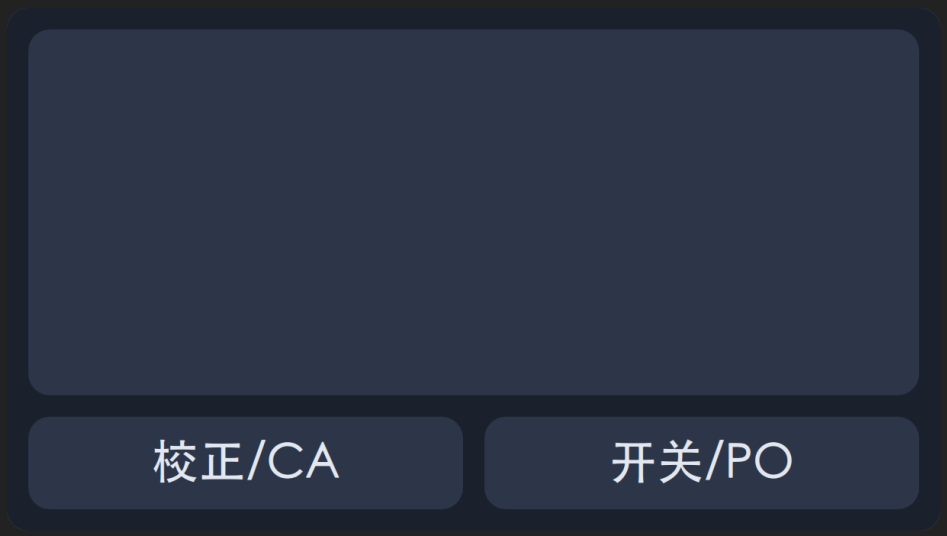


Figure. Dialer Pane on Server Side

The Final Assembly! (MyInterface.qml)

After each individual components have been defined, the only remaining job is to glue them together:

```
Rectangle {
        implicitHeight: 500
        implicitWidth: 640

        objectName: "rootRectangle_myInterface"
        id: rootRectangle_myInterface
        property bool isClient: MyServer ? MyServer.role_q === 1 : true
        property bool isServer: !isClient
        property double x_m: MyServer ? MyServer.xRatio_m_q : 0
        property double y_m: MyServer ? MyServer.yRatio_m_q : 0
        property bool debuggerShow: mouseArea_debuggerShow.pressed
        property string dispText: MyServer ? MyServer.currentMessage_q : "NOT IN SERVCE\nNOT IN
SERVICE"
        Rectangle {
                id: rectangle_blurFrame
                anchors.fill: parent
                color: MyStyle.color_neutral800
                MyDisplay {
                        id: myDisplay_myDisplay
                        anchors.left: parent.left
                        anchors.right: parent.right
                        anchors.top: parent.top
                        height: parent.height * 0.2
                        anchors.margins: MyStyle.param_lineWidth * 10
                        numberOfLines: 2
                        dispText: rootRectangle_myInterface.dispText
                }

                MyReadingsObserver {
                        id: myReadingsObserver_myReadingsObserver
                        visible: isClient
                        anchors.top: myDisplay_myDisplay.bottom

                        height: parent.height * 0.05
                        anchors.left: parent.left
                        anchors.right: parent.right
                        anchors.margins: MyStyle.param_lineWidth * 10
                        xVal: x_m
                        yVal: y_m
                }

                MyDialer {
                        id: myDialer_myDialer
                        anchors.top: isClient ? myReadingsObserver_myReadingsObserver.bottom :
myDisplay_myDisplay.bottom
                        anchors.bottom: parent.bottom
                        anchors.left: parent.left
                        anchors.right: parent.right
                        anchors.margins: MyStyle.param_lineWidth * 10
                        isClient: !isServer
                        onButtonClicked: buttonText => {
                                console.log("BUTTON_" + buttonText)
                                if (MyServer) MyServer.execute("BUTTON_" + buttonText)
```

```
                        }
                }
        }

        FastBlur {
                opacity: debuggerShow ? 1.0 : 0.0
                Behavior on opacity {
                        SpringAnimation {
                                spring: 1
                                damping: 0.2
                        }
                }
                source: rectangle_blurFrame
                anchors.fill: parent
                radius: 40
        }

        Rectangle {
                id: rectangle_debugger
                x: myDisplay_myDisplay.x
                y: myDisplay_myDisplay.y
                anchors.left: parent.left
                anchors.right: parent.right
                anchors.top: parent.top
                //              color: "transparent"
                height: debuggerShow ? myDialer_myDialer.height : myDisplay_myDisplay.height
                Behavior on height {
                        NumberAnimation {
                                easing.type: Easing.InOutQuad
                        }
                }
                color: MyStyle.color_neutral300
                radius: MyStyle.param_lineWidth * 10
                anchors.margins: MyStyle.param_lineWidth * 10
                visible: true
                opacity: debuggerShow ? 0.5 : 0.0
                Behavior on opacity {
                        SpringAnimation {
                                spring: 1
                                damping: 0.2
                        }
                }
                MyDebugger {
                        anchors.fill: parent
                        anchors.margins: MyStyle.param_lineWidth * 10
                }
                MouseArea {
                        id: mouseArea_debuggerShow
                        anchors.fill: parent
                }
        }
}
```

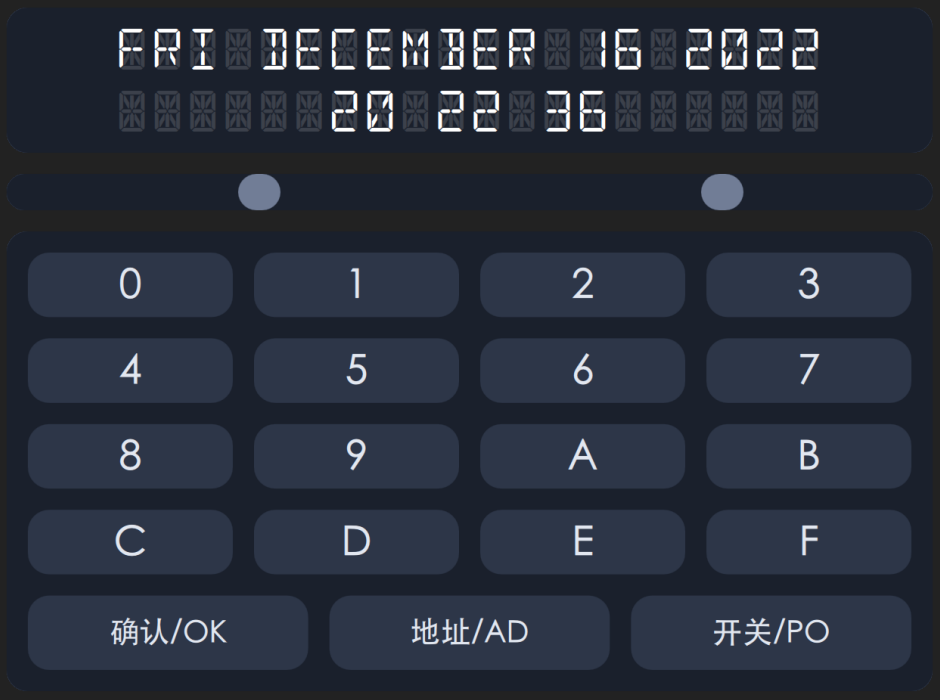


Figure Client-Side Full Interface Design

Figure. Server-Side Full Interface Design

Design Testing

The final project is tested on two Android Devices, and one PC Device. No obvious bugs have been detected so far. However, as this is a pure software project with very little hardware design element in it, all functional testings are completed during the prototyping stage, and after the final integration it would be the users' job to report bugs. Unsuccessful Attempts.

Debugging Console

To make users aware of the running status, a minimal debugging console is embedded in the software. To enable it, users can press the digital display panel, and all logging information will be available. This console is useful whenever there are unexpected disconnection or socket errors.

```
Rectangle {
        implicitHeight: 480
        implicitWidth: 400
        id: rootRectangle_myDebugger
        objectName: "rootRectangle_myDebugger"
        color: "transparent"
        border.color: "#ffffff"
        clip: true
        Text {
                anchors.fill: parent
                text: MyServer ? MyServer.debuggerMessages_q : "-> Debugger Initializing..."
                color: MyStyle.color_neutral900
                font.family: "YaHei Fira Icon Hybrid"
                font.pixelSize: MyStyle.param_fontSize
                wrapMode: Text.Wrap
                fontSizeMode: Text.VerticalFit
        }
}
```

Summary

In conclusion, this project dives deep into the QT and QML Framework. With the JavaScript-like QML Engine, this software is able to render a beautiful graphical user interface with smooth transition. In this project, many software patterns are employed such as the dynamic model-view-controller patterns for the platform-adaptive buttons, signals and slots interactions between C++ and QML Element using the Meta-Object system.

This project also explores the possibility of learning how to use a library without a clear example, since the amount of information available on explaining how to establish classic bluetooth connections between devices is

extremely limited in Qt's official documentation. It also signifies the importance of detailed documentation for developers.

Future Work

One imperfection of this project is the signal handling algorithms. As mentioned above, the current signal stabilizing techniques are acceptable but have rooms for improvement. In addition to readings from the tilt sensor, it is advisable to track the readings from the gyroscope. The gyroscope is able to detect the angular velocity, with which we can apply a Kalman Filter to smooth out the curve by making predictions of the next reading, comparing that with the actual reading from both sensors, and calculating optimized outputs.

Apart from that, it is also possible to explore other communication standards and integrate them into the software. Common ones would include ZigBee, 5G, NFC. Some other brutal protocols such as hearable sound, or even constantly-moving two-dimensional barcode using some advanced image processing algorithms.

Final Presentation

A full video explaining the software usages is available. The video link is provided under the title.