Displaying Computerized ECG Recordings and Vital Signs on Windows Phone 7 Smartphones

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Abstract

With the Windows Phone 7 Microsoft will release a new mobile operating system this fall. By displaying ECG recordings and vital signs on this new platform it could be shown that devices with the new mobile operating system can be used as mobile monitoring units. Due to their multiple wireless communication capabilities they can be useful for the mobile transmission of physiological data to telemedicine healthcare centers or personalized health portals.

The development of applications for Windows Phone 7 is quite easy by using the popular development platform Silverlight. At this juncture the design of the graphical user interface is separated from the development of the code.

By using this platform it is possible to achieve a mobile monitoring application which can be used everywhere.

1. Introduction

Because smartphones are popular in all age groups, one could posit that they might be useful as a portable health monitor for physiological parameters and as an ECG viewer device. Smartphones support many communication standards like GSM, UMTS, WIFI and Bluetooth so physiologically monitored parameters could be sent wireless from anywhere in the world to telemedicine healthcare centers. But due to the rapid evolution in the mobile market existing software is often not reusable for the new upcoming mobile devices. Therefore a new mobile biomedical application was developed to test and to judge the suitability of the new Windows Phone 7 mobile platform as an ECG viewer device and a vital sign viewer in the future (Figure 1). Smartphones can support two telemedical workflows. They are able to communicate directly with physiological body sensors mainly using wireless Bluetooth communication or they can be used as a wireless viewing client retrieving physiological data from a biomedical central station (Figure 2). In the first workflow scenario the smartphone is able to do realtime display and storage of the physiological data and it can also forward the data to a central monitoring station using any wireless communication standard. In the second workflow the smartphone is a mobile workstation that can remotely monitor vital signs and alarms from multiple patients.

Figure 1: 4 Channel ECG and pulse wave on a Smartphone Emulator. Attention: ECG and pulse wave are form different simulators and therefore not synchronized.

2. Methods

Visual Studio 2010 Express for Windows Phone was used to develop the new mobile ECG and vital sign viewer. The application does run on the Windows Phone 7 Emulator and Device. The software emulator was released by Microsoft to allow new software development prior to the release of the Windows Phone 7 smartphones. The devices will be released to the public at the end of October 2010. It was possible to test the application successfully on a pre-series device. Silverlight (a mix of

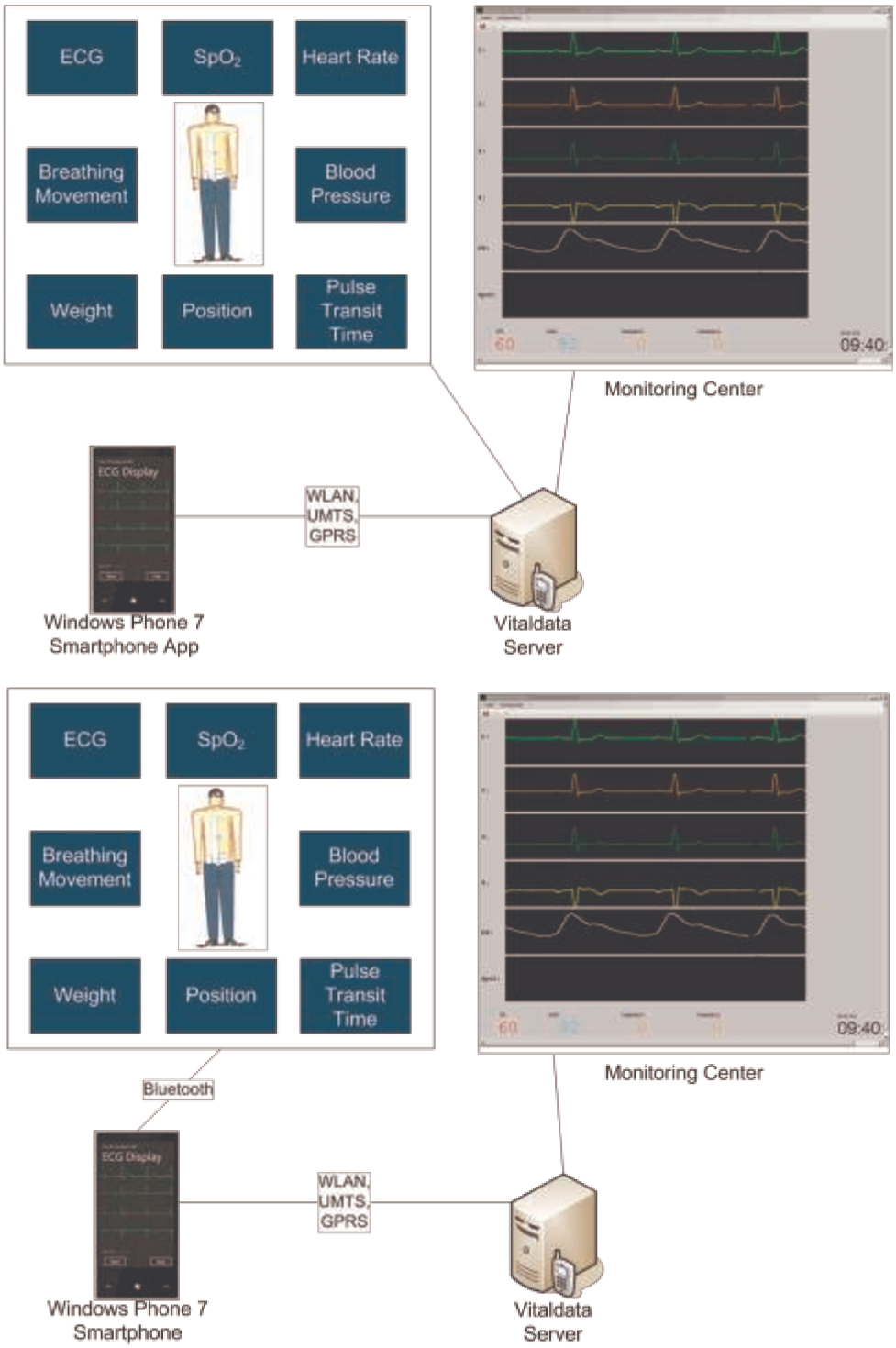

Figure 2: There are two possible ways to use the new Windows Phone 7 smartphone as an ECG monitor: It can be used as a gateway for the collected data so that the patient can watch his/her own ECG (lower image) or it can be used as a mobile monitoring center for nurses and doctors (upper image).

Definition of the grid where the ECG will be displayed in

```
<UserControl x:Class="de.skPhone7Components.skPhone7ECGDisplay.ECGDisplayUserControl">
    <!--Some more code-->
    <Grid x:Name="gridECGDisplay" Background="#FF1F1F1F">
        <Grid.RowDefinitions>
            <RowDefinition></RowDefinition>
            <RowDefinition></RowDefinition>
            <RowDefinition></RowDefinition>
            <RowDefinition></RowDefinition>
            <RowDefinition></RowDefinition>
        </Grid.RowDefinitions>
        <Polyline Name="ekglineI" Grid.Row="0" Stroke="LimeGreen" StrokeThickness="2"></Polyline>
        <Polyline Name="ekglineII" Grid.Row="1" Stroke="LimeGreen" StrokeThickness="2"></Polyline>
        <Polyline Name="ekglineV1" Grid.Row="2" Stroke="LimeGreen" StrokeThickness="2"></Polyline>
        <Polyline Name="ekglineV2" Grid.Row="3" Stroke="LimeGreen" StrokeThickness="2"></Polyline>
        <Polyline Name="pwLine" Grid.Row="4" Stroke="Red" StrokeThickness="2" Margin="0,0,0,46"></Polyline>
        <Polyline Name="blackLineI" Grid.Row="0" Stroke="#FF1F1F1F" StrokeThickness="20"></Polyline>
        <Polyline Name="blackLineII" Grid.Row="1" Stroke="#FF1F1F1F" StrokeThickness="20"></Polyline>
        <Polyline Name="blackLineV1" Grid.Row="2" Stroke="#FF1F1F1F" StrokeThickness="20"></Polyline>
        <Polyline Name="blackLineV2" Grid.Row="3" Stroke="#FF1F1F1F" StrokeThickness="20"></Polyline>
        <Polyline Name="blackLinePW" Grid.Row="4" Stroke="#FF1F1F1F" StrokeThickness="20"></Polyline>
        <TextBlock Foreground="LightBlue" Height="34" HorizontalAlignment="Left" Margin="12,56,0,6" Name="tbSpO2"
            Text="SpO2: " VerticalAlignment="Center" Width="140" Grid.Row="4" FontSize="20" />
        <TextBlock Foreground="Red" Height="34" HorizontalAlignment="Right" Margin="0,56,0,6" Name="tbHR" Text="HR: "
            VerticalAlignment="Center" Width="140" Grid.Row="4" FontSize="20"  />
    </Grid>
</UserControl>
```

Implementation of the defined ECG grid into the application page

```
<Grid x:Name="ContentGrid" Grid.Row="1">
    <Button Content="Open" Height="90" HorizontalAlignment="Left" Margin="0,587,0,0" Name="bOpen" VerticalAlignment="Top"
        Width="174" Click="bOpen_Click" />
    <my:ECGDisplayUserControl Margin="6,6,6,80" Name="ECGPanel" DataContext="{Binding}"></my:ECGDisplayUserControl>
    <Button Content="Stop" Height="90" HorizontalAlignment="Left" Margin="306,587,0,0" Name="bStop"
        VerticalAlignment="Top" Width="174" Click="bStop_Click" />
</Grid>
```

Figure 3: XAML Code example. New Windows Phone 7 with Silverlight makes it easy to develop the display of vital signs.

C# and XAML) was used for coding. XAML [2] is used behavior of the GUI is implemented by the "code-behind" programming language, in this case C#. Hereby a separation of behavior and appearance is achieved. The graphical user interface was designed to display continuous, digitally recorded ECG data, pulse wave data and also discrete values of heart rate and oxygen saturation. The values can be sent to the device via WIFI or any other wireless connection. In the new Windows Phone 7 it is currently not possible to use TCP socket connections, so a WCF service was developed [5,6]. This Web service uses a HTTP binding which is not a very fast way to transfer the collected data. Because of this issue the next step will be to compress the data before the transmission. On the smartphone the data have to be read out of the transferred byte-array which is organized like an EDF-file without the header. After that, the received data have to be scaled to fit the small screen size of the Smartphone and they have to be converted to the data type PointCollection. The refresh-period of the displayed ECG waves is controlled by a Timer-component so that 25 frames per second (fps) can be achieved.

3. Results

Using the latest Windows Phone 7 development tools a mobile biomedical ECG viewer application on the smartphone could be developed with minimal effort. The limiting factor of monitoring and viewing the ECG tracings is the small smartphone display size. Especially for elderly people the small touchscreen may be difficult to see and operate. Because of the small display size the presentation of a reasonable 12-lead ECG is limited. Nevertheless, smartphones can be useful for the mobile transmission of physiological data [3] to telemedicine healthcare centers or personalized health or fitness portals due to their multiple wireless communication capabilities. This kind of application can also be used by nurses or physicians to monitor the patients ECG or to receive and to view ECG alarms (Figure 2). By using smartphones nurses and physicians can have the feasibility of a small, portable and easy to use monitoring application. Compared to the old Windows Mobile versions (Figure 5) the new Windows Phone 7 makes it a lot easier to develop a biomedical ECG viewer for a mobile operating system even if currently there are some obstructive restrictions. Also the progress of the used hardware (CPU, connectivity components, display) brings out a lot of benefits. With the capacitive touch screen of the Windows Phone 7 devices it is a lot easier to operate the device with the fingers than it was with the old, stylus operated Windows Mobile versions. The current restrictions of Windows Phone 7 complicated the

Figure 4: Application on a real Windows Phone 7. 3.5" touchscreen Resolution 480-by-800 pixels. The approximate size of the smartphone is : 116 x 59 x 16 mm. Attention: ECG and pulse wave are form different simulators and therefore not synchronized.

Figure 5: A biomedical ECG viewer shown on an old Windows Mobile 6.0 device with a 2.8" touchscreen and a screen resolution of 240-by-320 pixels [4].

development at a few points: A direct TCP socket connection could be much more efficient than a Web service and saving files outside the isolated storage will be eligible.

4. Discussion and conclusions

Visual Studio, the Microsoft software development platform, does consist for more than two decades now. Up to Windows Mobile 6.5 it could be used to develop computer or smartphone application with the same computer language and (mostly) the same code. But for the new Windows Phone 7 software development some restriction were added. TCP socket connections which are very helpful for a wireless data exchange are currently not supported. Also the storage of the data in a filewise manner has to be changed into the isolated storage methodology. We have demonstrated that biomedical programs for smartphones can easily be developed using standardized Windows programming tools such as C# and Silverlight. The new Windows Phone 7 with its different possible ways of connection makes it easy for the user to view multichannel ECGs and discrete vital parameters wherever he wants to view them.

References

[1] Rozanski U, Silverlight 3. Heidelberg, Munich, Landsberg, Frechen, Hamburg: MITP, 2010:17 - 22.

[2] Xu J, Practical WPF Charts and Graphics: Advanced chart and graphics programming with the Windows Presentation Foundation. New York: APRESS, 2009: 1 - 11.

[3] Allen Cheng, Real-Time Cardiovascular Diseases Detection on a Smartphone. mHealth Summit 2009. [Online]. 2009. [cited 2010 Sept 28]. Available from: URL: http://research.microsoft.com/en-us/events/mhealth2009/cheng-poster.pdf

[4] Klug Stefan, Erstellung einer Software zur Anzeige physiologischer Messwerte (Bachelor thesis). Herne, Gelsenkirchen: FH Gelsenkirchen, 2008: p. 22.

[5] Chappell David, Introducing Windows Communication Foundation in .NET Framework 4. [Online]. 2010. [cited 2010 Oct 05]. Available from: URL: http://msdn.microsoft.com/library/ee958158.aspx

[6] Microsoft Corp., Networking for Windows Phone. [Online]. 2010. [cited 2010 Oct 05]. Available from: URL: http://msdn.microsoft.com/en-us/library/ff637320(VS.96).aspx

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