Developing the research prototypes to a software product, a case study of medical imaging application

KN Manjunath Ph.D.
Faculty in Computer Science and Engineering,
Manipal Academy of Higher Education,
kn.manjunath@ieee.org
(Formerly Consultant, SIEMENS Healthineers)
Presentation outline

• Introduction - 5 min
• MIP research a case study - 5
• Overview of research - 10
• Prototype to product phases - 10
• Novelty and business idea - 10
• Discussion - 10
Introduction

Discipline and domain
Interdisciplinary work - Radio-diagnosis + Gastroenterology + Engineering disciplines, Medical Image Processing stream.

Specific area of investigation
Solving the technical problems in computer aided diagnosis of colon polyp using image processing techniques.

What is needed in polyp diagnosis

Key determinants of colon cancer
Size, shape, type and grade of dysplasia of polyp

Polyp size classification
1-5mm, 6-9mm, >10mm

Polyp shapes
Sessile, flat, pedunculated and mass

Fig. 1: CTC workflow (Image source: Sliesenger, 2010, SIEMENS, 2017, Kalender, 2006)

Fig. 2: Polyp growth (Sleisenger 2010)

Fig. 3: Polyp growth as seen on axial MPR
**Motivation**
The rationale behind this study was to find novel Image Processing techniques through exploratory research to identify the polyps accurately through CTC software.

**Problems statement**
Inaccurate measurement of polyp in computer aided systems can mislead the diagnosis (problem). Improved engineering solution is required for Radiologists (clients) and they evaluate the research results (scope).

**Objectives**
a) Colon segmentation,
b) Virtual (electronic) colon cleansing and
c) Measuring the smaller polyps of size less than 10 mm

**Implementation:** C# (NET™ 4.5) + MS Volume rendering SDK™ (Melancoln, 2012) + MarchingCube (Paul, 2014).

**Image source**
National Cancer Institute (NCI) and National Institute of Health (NIH), USA (Clark, 2017)
Clear separation of user interface, domain logic and technical services (MKN et. al. 2017, SCIE, 10.1007/s11548-017-1615-4)

**Fig. 4: The research and development phases**
Fig. 5: The research and development phases (MKN, et. al., DOI:10.31557/APJCP.2019.20.2.629)

Software pattern:
Based on Model-View-Controller architectural pattern

Computing Resources:
Software:
Microsoft - Win 2012 Server 64 bit, VS 2010 with SP1, .NET 4.5, Volume Rendering SDK, Marching cube.

Hardware:
Intel Xeon® CPU E52620 2.0GHz, NVidia CUDA 4GB GPU, 64 GB DDR3 RAM
Materials and methods

Image source (secondary data) and CTC protocol
• National Cancer Institute, USA (Clark, 2016), ACRIN 6664 (www.acrin.org, 2016) protocol, fecal tagged

Ethical committee clearance
KMC/KH IEC 211/2014 dated 9th April, 2014

Dataset validation
Validated for type 1 and type 2 attributes against DICOM 2012 standard (DICOM PS 3.2, 2012)

<table>
<thead>
<tr>
<th>Parameter</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>$ST$ in mm</td>
<td>{ 1.0, 1.25, 2.5 }</td>
</tr>
<tr>
<td>$kVp$ (peak kilo voltage)</td>
<td>{ 100, 120 }</td>
</tr>
<tr>
<td>$mA$ (milli ampere)</td>
<td>{ 60, 100, 120, 140, 141, 200, 240, 250, 280, 300 }</td>
</tr>
<tr>
<td>Pixel size in mm</td>
<td>{ 0.58 – 0.93 } square size pixels</td>
</tr>
<tr>
<td>Image Resolution</td>
<td>512,512</td>
</tr>
<tr>
<td>Radiometric Resolution</td>
<td>16 bit</td>
</tr>
<tr>
<td>Patient positions</td>
<td>{ FFS, FFP, FFS+FFP, HFS+HFP } Prone: Supine:</td>
</tr>
<tr>
<td>CT images/position scan</td>
<td>~ 1000 (for both FFS and FFP)</td>
</tr>
<tr>
<td>Age</td>
<td>{ 40...90 } both male and female</td>
</tr>
<tr>
<td>Machine manufacturer</td>
<td>SIEMENS Sensation 16, 64™, GE Lightspeed 16™, Philips Brilliance 16™, Toshiba 64™</td>
</tr>
<tr>
<td>Multi Detector CT</td>
<td>8/16 slices</td>
</tr>
</tbody>
</table>

Table 1: CTC Image acquisition details
### Research Methodology

#### Table 2: Research components applied (Kothari, 2004)

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Hypothesis</strong></td>
<td>( H_0 ) – IP doesn’t influence sensitivity, ( H_a ) – IP influences the sensitivity</td>
</tr>
<tr>
<td><strong>Type</strong></td>
<td>Experimental (method of study), Exploratory (intent)</td>
</tr>
<tr>
<td><strong>Approach</strong></td>
<td>Qualitative (subjective) + Quantitative (objective)</td>
</tr>
<tr>
<td><strong>Variables</strong></td>
<td>Dependent + Independent + Extraneous variables</td>
</tr>
<tr>
<td><strong>Experimental error</strong></td>
<td>Follow right CTC protocol</td>
</tr>
<tr>
<td><strong>Sampling design</strong></td>
<td>Stratified sampling, ( n = 150 ), ( N = 950 )</td>
</tr>
<tr>
<td><strong>Data collection</strong></td>
<td>Questionnaire (secondary data)</td>
</tr>
<tr>
<td><strong>Data analysis</strong></td>
<td>Tabulated and classified. No edit (unethical, incompleteness)</td>
</tr>
<tr>
<td><strong>Consistency check</strong></td>
<td>Reliability + Suitability + Adequate (DICOM CT validation)</td>
</tr>
<tr>
<td><strong>Design of experiments</strong></td>
<td>Principle of randomization + Randomized Block design</td>
</tr>
<tr>
<td><strong>Hypothesis testing</strong></td>
<td>“Paired t” test + Volumetric overlap computation</td>
</tr>
<tr>
<td><strong>Variance analysis</strong></td>
<td>No analysis due to variation in independent variables</td>
</tr>
</tbody>
</table>
Understanding the requirements and a proper design is more than anything and everything.

• This is not seen in research environment
• It doesn’t mean that it is not possible in research

Fig. 6: The SDLC phases
How to write the proper code

```csharp
/// <summary>
/// This method
/// 1. Computes the number of pixels in the manually segmented region
/// 2. Does pixel to pixel matching between the results and the reference
/// 3. Computes the overlap error
/// 4. Updates the UI with the values
/// </summary>
private void ValidateResult_Click(object sender, RoutedEventArgs e)
{
    // 1. The list is having duplicate entries (due to bug in mousemove andmousedown in 2D axial segment). Consider distinct elements.
    referenceContour = referenceContour.Distinct().ToList();

    // 2. From the contour points, find those voxels which has same y coordinate. This gives the pair of geometrical locations.
    var result = from l in referenceContour group l by l.Y into r select new { key = r.Key, Value = r.ToList() };

    // A new list for matching the voxels of segmented volume and reference
    List<System.Drawing.Point> pointsInResultContour = new List<System.Drawing.Point>();
    List<System.Drawing.Point> pointsInIntersection = new List<System.Drawing.Point>();
    List<System.Drawing.Point> pointsInUnion = new List<System.Drawing.Point>();

    // Variables to count the number of pixels within the boundary and for finding the common pixels between result and reference.
    int numberOfpixelsInReferenceContour = 0, numberOfpixelsInResultContour = 0, Intersection = 0;

    // For each pair of left and right points
    foreach (var avar in result)
    {
        double ak = avar.key; List<System.Drawing.Point> av = avar.Value;

        // Find the extreme left and extreme right points
        int xCoordinate_Min = av.Min(System.Drawing.Point)(ap => ap.X); int xCoordinate_Max = av.Max(System.Drawing.Point)(ap => ap.X);
        int yCoordinate_Min = av.Min(System.Drawing.Point)(ap => ap.Y); int yCoordinate_Max = av.Max(System.Drawing.Point)(ap => ap.Y);

        // Count the number of pixels between left and right in each scan line
        numberOfpixelsInReferenceContour += (xCoordinate_Max - xCoordinate_Min);

        // Collect all the points that happens within the left and right points (these points are properly checked with the simulation
        for (int col = xCoordinate_Min; col < xCoordinate_Max; col++)
        {
```

Document every line of program for better understandability
**Different software testing methods**

**ACCEPTANCE TESTING:** Software testing where a system is tested for acceptability. The purpose of this test is to evaluate the system’s compliance with the business requirements.

**SYSTEM TESTING:** Where a complete and integrated software is tested.

**INTEGRATION TESTING:** Interaction between the modules is checked.

**UNIT TESTING:** Individual units/components of a software are tested. Involves testing the class methods.

- In research we test the **results** whereas in software development we test **both the result and the application**. In both cases we use statistical analysis methods.

- In research environment achieving all these testing methods is very time consuming.

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**Fig 7: Different levels of software testing**
Testing the class methods

Unit testing frameworks
Nunit – C#, Junit – Java, CPPTest – C++

- Each test case represents one distinct input check.
- The test cases are mapped with the requirement key.
Isotropic voxel creation

- ST or Size\(_z\) = \{0.75, 1.25, 2.5\} mm
- Size\(_x\) = \{0.546875 – 0.9765625\} mm,
- Applied linear interpolation.
- \(\mathbb{R}^2\) to \(\mathbb{R}^3\) conversion through matrix.

\[
\begin{align*}
  \text{if} & \left( x \leq c - 0.5 - \frac{w - 1}{2} \right), \text{then} & y &= y_{\text{min}} \\
  \text{else if} & \left( x > c - 0.5 + \frac{w - 1}{2} \right), \text{then} & y &= y_{\text{max}} \\
  \text{else} & y &= \left( x - (c - 0.5) \right) \cdot \left( y_{\text{max}} - y_{\text{min}} \right) + y_{\text{min}} 
\end{align*}
\]

Fig. 8: Linear interpolation in z axis

Fig. 9: Surface rendering and direct volume rendering in 3D with variable slice thickness (5mm, 2.5, 1.25 and 0.75 respectively).

Contd..
Problem: Delineation of colon wall at the base of the colonic structures was not addressed so far.

Objective: To segment the colon without losing colonic structures.

Methodology: Based on prior knowledge of colon distension grading \((d>2\text{cm})\). (MKN et al., 2016, JMIHI, SCI, 10.1166/jmihi.2016.1786)

\[
z = T(r) = 255 + \left( \frac{f(m, n) - \min(f(m, n))}{\max(f(m, n)) - \min(f(m, n))} \right)
\]

Contrast correction

\[
V_{out(i=0,255)} = A * \left( \frac{V_{in}}{255} \right)^{y}
\]

Gamma correction

\[
1. G_m(m, n) = \frac{f(m + 1, n) - f(m - 1, n)}{G_m^2 + \text{factor}^2}
\]

Adaptive smoothing

\[
\text{weight}(m, n) = e^{-\frac{G_m^2 + \text{factor}^2}{2 \cdot \text{factor}^2}}
\]

\[
\text{total} = \sum_{i=-1}^{1} \sum_{j=-1}^{1} f(m + i, n + j) \cdot \text{weight}(m + i, n + j)
\]

\[
\text{weighttotal} = \sum_{i=-1}^{1} \sum_{j=-1}^{1} \text{weight}(m + i, n + j)
\]

Segmented colon

\[
S = (c, f) \Rightarrow S_0 = (c, f_0)
\]
**Results (3/10) - Colon segmentation**

- **Final result**
  - Fig. 11: Volume rendering of segmented colon and colon interior

- **Validation**
  - Supervised evaluation method (Observer’s rating).
  - Verified with Philips DICOM Viewer™ & SIEMENS Syngo Fast View™
  - Volumetric overlap calculation: Achieved 95.2% accuracy.

- **Key findings**
  - Fig. 13: Delineation of base of the colonic structures

- **Inference**
  1. Colon wall is delineated, 2. Boundary thickness – 1 pixel, 3. No segmentation leaks. 4.

\[
\text{Accuracy} = \frac{A \cap B}{A \cup B} \times 100
\]

- Fig. 12: a) set of slices, b) Reference, c) result

- Fig. 14: DRR of unsegmented volume and surface and direct volume rendered images

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**Problem:** Incomplete cleansing, soft tissue erosion, pseudo enhanced soft tissues.

**Objective:** To virtually clean the tagged colonic content to solve above problems.

**Methodology:** Based on prior knowledge of material composition of colonic contents (MKN et. al., 2015, APJCP, SCI, [10.7314/APJCP.2015.16.18.8351](#)).

**Step 1:** Theoretically calculate the HU of colonic contents using formula (NIST, 2016).

\[
keV \rightarrow \mu_t(x,y,z) = \frac{1000 \cdot (\mu_t(x,y,z) - \mu_{\text{air}})}{\mu_{\text{w}} - \mu_{\text{w}}} \rightarrow \text{CT Number}(x,y,z)
\]

\[
CT + m + y \intercept \rightarrow HU(x,y,z) = \frac{HU - P1 \cdot z^{-1}}{W} \rightarrow f(x,y)
\]

**Step 2:** Create lookup table of colonic contents and its HU range.

**Step 3:** Adaptive EC steps

\[
V_{\text{output}}(x, y, z) = \begin{cases} 
\text{Min}_{HU}, \text{if } -1024 HU < [\forall V_0(x, y, z) \in S_0] \leq -850 HU \\
\text{Min}_{HU}, \text{if } [\forall V_0(x, y, z) \in S_0] \geq 600 HU \\
V_0(x, y, z) + HU, \text{if } 200 HU < [\forall V_0(x, y, z) \in S_0] \leq +600 HU \\
\text{Min}_{HU}, \text{if } -700 HU < [\forall V_0(x, y, z) \in S_0] \leq +600 HU
\end{cases}
\]

**Table 3:** Practically observed HU from clinical studies

<table>
<thead>
<tr>
<th>Key</th>
<th>Value</th>
<th>From clinical studies (HU range) [3]</th>
</tr>
</thead>
<tbody>
<tr>
<td>(kVp)</td>
<td>(colonic content)</td>
<td>80</td>
</tr>
<tr>
<td>80</td>
<td>Air</td>
<td>-1000±10</td>
</tr>
<tr>
<td>100</td>
<td>Air</td>
<td>+144</td>
</tr>
<tr>
<td>120</td>
<td>Air</td>
<td>+62</td>
</tr>
<tr>
<td>..</td>
<td>Water</td>
<td>0±5</td>
</tr>
<tr>
<td>..</td>
<td>Fat</td>
<td>-152</td>
</tr>
<tr>
<td>..</td>
<td>CO₂</td>
<td>-1000±25</td>
</tr>
</tbody>
</table>

List < kVp, List < colonic contents, HU range ≥
Results (5/10) - Electronic cleansing

Fig. 20: Results showing different levels of contrast and cleansed colon (row 1, 3: Original axial images, row 2, 4: Cleansed colon without losing colonic structures.

- **Validation**: Compared measurements with GT (Johnson, 2008).

- **Key findings**: Completely cleansed, no soft tissue erosion and pseudo enhance voxels are corrected.

- **Inference**: Method can be used with images acquired with various levels of kVp.

Fig. 19: 2D MPR and 3D view after cleansed colon

Fig. 21: Polyp size compared with GT

<table>
<thead>
<tr>
<th>Size in mm</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5</th>
<th>6</th>
<th>7</th>
<th>8</th>
<th>9</th>
<th>10</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ground Truth</td>
<td>7</td>
<td>10</td>
<td>25</td>
<td>9</td>
<td>16</td>
<td>11</td>
<td>18</td>
<td>16</td>
<td>11</td>
<td>14</td>
</tr>
<tr>
<td>Proposed method</td>
<td>7.3</td>
<td>9.6</td>
<td>24.5</td>
<td>8.2</td>
<td>16.8</td>
<td>11</td>
<td>18</td>
<td>15.9</td>
<td>11</td>
<td>13.9</td>
</tr>
</tbody>
</table>

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**Problem:** Accuracy in smaller polyp measurement is poor.

**Objective:** To measure smaller polyp of size <10mm.

**Methodology:** Based on knowledge of polyp height ($h<7mm$), height to width ratio ($h=1.5w$ or $h=1.5w$) (Summers, 2009) and intensity distribution an automated method is developed. (MKN et. al., 2017, JCARS, SCIE, 10.1007/s11548-017-1615-4)

Shape descriptor

$$S(S_0) = \bigcup_{k=0}^{K} S_k(S_0) = S_k^1$$

Erosion using Structuring element

$S_k^1(S_0) = (S_0 \ominus kB) - (S_0 \ominus kB)^oB$

$K = \max\{k| (S_0 \ominus kB) \neq \emptyset\}$

Retaining descriptor of desired structure

$S_k^1 = \neg \{(\forall v_k \in S_k^1) \cap (\forall v_0 \in S_0)\}$

Gram Schmitt orthogonalization

$$\vec{v}_1 \cdot \vec{v}_2 = 0$$
Results (7/10) - Smaller polyp measurement

- **Step 5:** 3D view of retained colonic structures after step 4

  ![Fig. 18.1: the 3D view of colon in which the colonic structures are shown in green color](image)

- **Step 6:** Measuring the structure height

  ![Fig. 18.2: Height calculation of colonic structures](image)

- **Step 7:** Measuring the structure width

  ![Fig. 19: Width calculation](image)

  ![Fig. 18.3: Reconstructed shapes from the shape descriptor](image)
Step 8: Automated delineation of smaller polyps

- Polyp: h<7mm
- Sessile: h<=1.5w
- Flat: h>=1.5w

Table 4: Sensitivity and specificity readings

<table>
<thead>
<tr>
<th>Polyp size (mm)</th>
<th>Polyp present</th>
<th>Polyp absent</th>
</tr>
</thead>
<tbody>
<tr>
<td>&lt;=10mm (n=42)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Test says “present”</td>
<td>TP = 35</td>
<td>FP = 2</td>
</tr>
<tr>
<td>Test says “absent”</td>
<td>FN = 5</td>
<td>TN = 9</td>
</tr>
</tbody>
</table>

Fig. 20: Smaller polyps identified (2D MPR and 3D volume rendered)

Statistical analysis

Polyp size measurement

Table 5: Results comparison

<table>
<thead>
<tr>
<th>Authors</th>
<th>Analysis scheme</th>
<th>No. of patients evaluated</th>
<th>No. of polyps actually present</th>
<th>TPR in %</th>
<th>TNR in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Lee et al. [9]</td>
<td>Per polyp</td>
<td>65</td>
<td>103</td>
<td>55.0</td>
<td>78.0</td>
</tr>
<tr>
<td>Wang et al. [15]</td>
<td>Per polyp</td>
<td>1125</td>
<td>106</td>
<td>83.0</td>
<td>Not reported</td>
</tr>
<tr>
<td>Johnson [20]</td>
<td>Per polyp</td>
<td>2531</td>
<td>547</td>
<td>75.0</td>
<td>86.0</td>
</tr>
<tr>
<td>Summers et al. [4]</td>
<td>Per polyp</td>
<td>1185</td>
<td>259</td>
<td>76.7</td>
<td>Not reported</td>
</tr>
<tr>
<td>Huang et al. [10]</td>
<td>Per polyp</td>
<td>29</td>
<td>53</td>
<td>90.0</td>
<td>Not reported</td>
</tr>
<tr>
<td>Johnson [32]</td>
<td>Per patient</td>
<td>477</td>
<td>65–77</td>
<td>Not reported</td>
<td>Not reported</td>
</tr>
<tr>
<td>Chu et al. [2]</td>
<td>Per patient</td>
<td>2531</td>
<td>40</td>
<td>90.0</td>
<td>86.0</td>
</tr>
<tr>
<td>Our method</td>
<td>Per polyp</td>
<td>45</td>
<td>40</td>
<td>87.5.0</td>
<td>82.0</td>
</tr>
</tbody>
</table>

Fig. 21: Size compared with GT (Johnson, 2008)

Validation

- Supervised evaluation technique.
- Sensitivity (TPR)=87.5%, specificity (TNR)=82%, PPV=94.45% and accuracy=86.26%.
- Paired t-test, @ CI=0.95, α=0.05,[t]=1.274 and p=0.218 => >0.0001. Measurements ⇔ GT.

Key findings

Polyps <10mm are recognized successfully.
Objective: To develop a method to visualize colon interior.

Methodology: Using clipping plane selection, visualization is provided.

Fig. 22: Reference line selection in 2D MPR and Parallel update of both 2D and 3D view using reference line selection on MPR. (MKN et. al., Image Science 2018, Gordon Research Conferences, Boston)
Results (10/10) - 2D view and 3D rendering

Fig. 24: Integration of MSVR framework (Melancon, 2012)

Fig. 25: 2D LUT from DICOM (DICOM, 2016) and visualization of segmented regions on 2D MPR

Contd..
Key findings

- **Colon segmentation:** 95.2% accuracy, through volumetric overlap calculation, colon wall properly delineated, **time:** 2 min for 500 CT slices,

- **Electronic cleansing:** Method can be used with images acquired with various levels of kVp, **time:** 6 min for 500 slices

- **Polyp measurement:** Sensitivity (TPR)=87.5%, specificity(TNR)=82%, **PPV=94.45%**, **accuracy=86.26%**, **time:** 3 min for 500 CT slices.
The prototype (2/2)

DICOM properties

Histograms

IP handling

varying the volume render parameters

Fig. 27: Time takes for each task in sequential run and through multithreading

8/7/2019

MAHE, Manipal
Innovation steps

3 Phases of a Simplified Innovation Process

Conception
- Requirement Analysis
- Idea Generation
- Idea Evaluation
- Project Planning

Implementation
- Development/Construction
- Prototype Development
- Pilot Application
- Testing

Marketing
- Production
- Market Launch & Penetration (National/International)

Fig. 28: The invention to innovation steps
Novelty and business idea (1/2)

Fig. 29: The key elements of the Radio diagnosis business model canvas

<table>
<thead>
<tr>
<th>Key Partners</th>
<th>Key Activities</th>
<th>Value Proposition</th>
<th>Customer Relationships</th>
<th>Customer Segments</th>
</tr>
</thead>
<tbody>
<tr>
<td>The Radiologist</td>
<td>Requirements gathering</td>
<td>Bug free and lightweight software</td>
<td>Long term repo</td>
<td>Radiology centers of tier 2 cities</td>
</tr>
<tr>
<td>The Gastroenterologist</td>
<td>Design and development</td>
<td>Low cost medical software product</td>
<td>Support through phone, e-mail and in person</td>
<td>Radiology centers run by NGO</td>
</tr>
<tr>
<td>The Research and Development Team</td>
<td>Validation of design and software testing</td>
<td>Needs less infrastructure and maintenance</td>
<td></td>
<td>Hopping to international market based on maturity in the product</td>
</tr>
<tr>
<td>The external software consultants</td>
<td>Copyrights, Patents, publications and Licensing</td>
<td>Flexibility to easily adapt to new requirements</td>
<td></td>
<td>Research prototype evaluation</td>
</tr>
<tr>
<td>Medical Imaging technologist</td>
<td></td>
<td>Mobile app support in native language</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Key Resources</th>
<th>Key Channels</th>
<th>Revenue Streams</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vertical and horizontal market</td>
<td>Professionals network sites</td>
<td>Pay per policy in case of cloud computing based service</td>
</tr>
<tr>
<td>Empowered and skilled human resources</td>
<td>App downloads through internet</td>
<td>Seeking funds from the supporting organization to reduce the expenditure on the patient</td>
</tr>
<tr>
<td>Hardware and software infrastructure</td>
<td>Delivery and support to Radiologists</td>
<td></td>
</tr>
</tbody>
</table>

Cost Structure

- Employment of skilled professionals and domain experts
- Procurement of high end hardware for faster performance
Novelty of the business idea

- The image processing prototype can be further **developed as a software product for any other medical imaging modalities** (CT, MRI, PET, and US) and for the diagnosis of the diseases.
- The product can be developed as a **mobile application** also that helps a patient to see his scan details in his language.
- It can be extended further as **cloud computing based application** to reduce the cost.

Implementation and commercialization

- **Transforming a research prototype in to a commercial product** involves lot of steps from Software engineering perspective. Validation is a key phase before releasing a software as a product (**IEC 62304**).
- To make it a light weight and the bug free software, the agile principles are implemented as part of the software development Life Cycle (**product**). The product can be evaluated in Radiology centers through clinical validation (**place**). Once it works as expected then its cost can be reduced further if we can go as cloud based service (**price**). Two tier hospitals can be considered as the potential market for releasing this product (**promotion**).
Inference

• Domain aspects has played major role in problem solving
• Thd dlls are developed which can be customized and extended based on the need.
• Research objectives are met and also they are demonstrated with proper UI.
• CTC CAA prototype can be used as an image processing framework for other modalities also.

Future work
Clinical validation is in progress and auditing against IEC62304 standards


Clark K et al., 2014, TCIA collection


References


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