Constructive 3D Visualization techniques on Mobile platform- Empirical Analysis

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Abstract: As per the concept of 3D visualization on mobile devices it is clear that it belongs to two approaches i.e. local and remote approach. According to the technological advances in mobile devices it is possible to handle some complex data locally and visualized it. But still it is a challenging task to manage real entities on mobile devices locally. Remote visualization plays a vital role for 3D visualization on mobile platform in which data comes from server. Remote approach for 3D visualization on mobile platform consist of various techniques, critical analysis of such techniques is focus into this paper. Also the main focus is on network aspects.

Keywords: *Local and remote approach, 3D visualization, mobile devices, various aspects*

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I. INTRODUCTION:

Wireless network and software protocols are responsible for the transmission of complex data from source to destination on mobile platform. Several mobile platforms are enabling to supports few features like protocol communication, graphics etc. so it's challenging task to perform 3D visualization on mobile platform. While transmitting data via wireless network various aspects affect on data such as bandwidth may construct fewer frames. Other aspects are threshold, frame rates, transmission delay, throughputs etc. those are focus in this paper.

Remote 3D visualization is used in wide areas such as complex urban environments, navigation, illustration, education such as for cultural heritage and rendering of large cities etc. and applied on some common types of data shown into following table.

Table 1: Classification of data and technique for remote visualization

Visualization category	Commonly applied data	Mostly utilized techniques
Remote visualization	Complex Textual and Graphical type data like -3D images - video Etc.	-Adaptation method -Clustering -Encoder, Decoder -Catching -Compression and decompression - Filtering - Optimization (Dynamic, Adoptive, Preprocessing) - Image Wrapping - Context modeling - Image streaming

As the mobile devices have so many limitations therefore 3D visualization of such wide area on mobile is a tedious task. This tedious task is made easier by server by providing various facilities with the help of various techniques at server side.

II. CONSTRUCTIVE 3D VISUALIZATION TECHNIQUES ON MOBILE DEVICES:

A. Cluster based rendering:

Fabrizio Lamberti et al. [1] developed three tired architecture based on client server. Architecture contains the RenderVedio SPU whose job is to extract the image data from frame buffer using glReadPixel() function and sends the video sequence to encode and streaming server components. These components have compression capability of render based frame sequence.

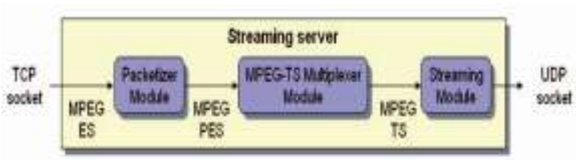

Fig.1 Structure of streaming server

Clustering might used to represent the variations in stock values of market data in the form of bar chart. In which positive value are represented from bottom to top on the bottom line and negative value from top to bottom on the upper line [2].

B. Adoptive techniques:

The content adaptation is a process of selection or modification of content (text, images, audio, and video), so that devices can present it. In this visualization is divided into two parts content and resource visualization. Resources are categorized according to their contents so there are different visualization modules for different resources [3].

Here is the reformulation of volume rendering using relevance function which is based on data to compute voxel opacity. There are two rendering techniques, Pre-Pixel Adoptive and Additive Volume Rendering. In Pre-pixel adoptive volume rendering ∂ (delta) is taken as classification function Additive technique keep away saturating colors from given pixel. Therefore there is use of same extinction function for all contribution [4].

C.Filtering:

Semantic Filtering: Filtering technique with semantic allows the intelligible visualization of geographic data to use multiple representation with different level of details [5]. Level of details classifies a category to state objects degree of interest and represent aggregation for objects of same or different category. This implementation gives a problem with mobile device due to limited architecture prototype.

Image Filtering: In case of image based rendering for the visualization of cylindrical panoramic image some filtering operations is performed to improve the image quality. Cylinders panorama rendering is performed by projecting pixel by pixel section of image observed on planer surface [6].

Information filtering: Geographic information retrieval (GIR) and geographic information filtering (GIF) from framework are responsible to perform filtering of irrelevant information. In semantic relevance similarity function is recognized and semantic distance is work out by using routes and point of interest. Therefore both physical and semantic distance functions are dignified as

R (**O**) = f (x → y) where x, y is the origin and destination features. Using this features, temporal and spatial functions can be expressed as

$R(spa) = f(_{dist}\overline{OD})$ for spatial and

$R(tem) = f(_{dist}\overline{T_oT_d})$ for temporal relevance.

Therefore semantic relevance is given by

$R(sem) = f(_{dist}\overline{S_oS_d})$ and

Combined relevance is express by

$R(total) = \sum_{i=1}^{n} w_j \cdot r_j$ where j is various relevance like spatial, temporal, semantic etc

r_j is the value of any relevance of type j and w_j is the weight of j which is depends on all kinds of context. To define the degree of relevance, a fuzzy set is used $\mu_A(x)\varepsilon$ [0,1] which assigns the value in between 0 and 1. This low and high relevance with threshold, scale and filtering scope can use for context modeling and adoptive method [7].

Cross filtering with interaction: Interaction in cross filtering provides detail view of multidimensional data by rapidly drilling down into arbitrary subset of multidimensional information.

For data transformation graphs cross filtering is developed. Four transformations is done by each view like grouping (γ), filtering (φ), projection/ visual encoding (π) and selection (σ). Author proposed cross filtering in hotel visualization as shown in fig.

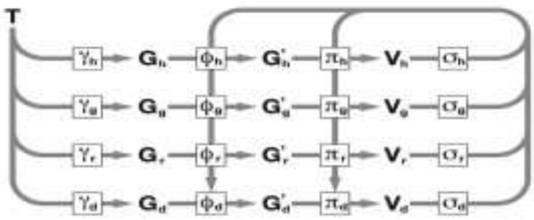

Fig:2 cross filtering queries

In fig. T indicates several concatenate entries in various hotels. G_h indicates group of hotels and G_g, G_r, G_d indicates group of guests, residences and dates respectively. Each group G is filtered denoted by G' and visually encoded (V) to view hotel information in table [8].

D Compression:

Compression using context modeling and residue packing: To efficiently compress the depth view and to improve the compression context modeling and residue packing techniques are used.

In context modeling and residue packing the complete residual or depth image is represented by array of integers i.e. I[x, y]. Encoder also find prediction Î[x, y] of next pixel value then encode the prediction residue value as

$$e[x, y]= I[x, y]- \hat{I}[x, y]$$

and in non hole area this value would be zero because their all context almost are zero. Therefore this prediction residue can packed to give the compacted sequence of residue i.e.$\{e_i\}$in the holes [9].

Predictive Compression: Pietro Zanuttigh et al. propose predictive compression technique which provides the depth visualization of 3D model with high quality on mobile device from distant server [10]. 3D warping was the image based rendering method which finds new predicted view from previous images with the help of z-buffer information. In image based rendering scheme (IBR),

$L_1(x)$ is current view of 3D model which communicate to the position of the user's camera (V_1) where $x \ \varepsilon \ Q_1 = [0, W_1] \times [0, H_1]$.

$x [x; y]^T$ is the pixel of L_1 whose 3D position is

$X = [x; y; Z(x; y)]^T$ where Z(x; y) is the z buffer content at x.

$L_2(x')$ indicates the next view located at

$V_2, x' \ \varepsilon \ Q_2 = [0, W_1] \times [0, H_1]$.

Therefore position $X' = [x'; y'; Z(x'; y')]^t$. 3D projective transformat$\hat{L}_{2(x,y)}$ also obtained in homogeneous coordinates.

The IBR prediction of is denoted by , z-buffer is denoted as Z(x, y).

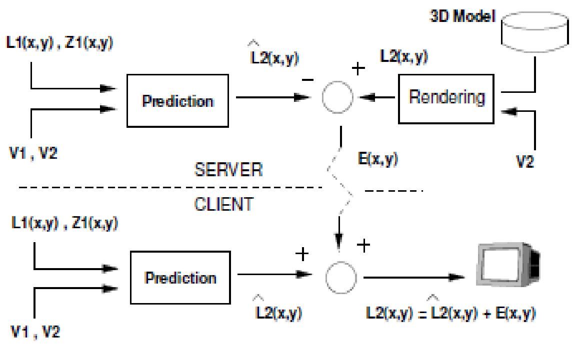

Fig:3 Predictive compression scheme.

Prediction schemes main theme is to compress and transfer prediction error E(x, y) [11].

Image compression and streaming with scheduling and QoE: Here author [12] proposed remote rendering approach. This remote rendering service is divided into two sides i.e. server side and client side. Number of applications given at server side is an event scheduler, 3D rendering module, QoE manager, JPEG encoder, and steaming module. While client side includes event generator, QoE manager, JPEG decoder, stream receiver and frame buffer viewer.

Server side 3D rendering module uses OpenGL for rendering; event scheduler manages command from user sides. QoE increases the resolution and compression quality.

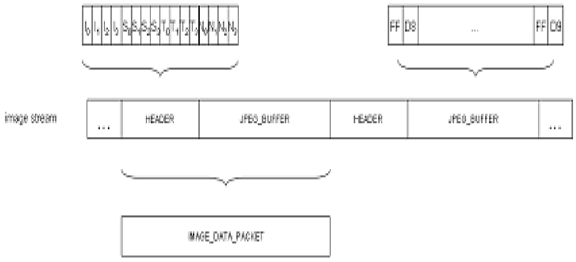

Fig:4 Image stream

I0-I_4 are different packets, then there is image size given by S, T is a temporary information about delivery of packets i.e. T_0-T_4, N indicates sequence of number of fields.

Data compression in static optimization: To minimize the data transmission rates, unrelated and unnecessary data, data compression technique is used. Data compression algorithm can made for hardware but it may work as software module such as V.42bis, which is not a benefit. Data compression algorithm create for software can lower compression rates for low processing power devices and high compression rates for high power devices [13].

Interactive video streaming with Compression and decompression: In communication flow of remote interactive visualization system architecture user requested data receive by session manager module of server, it also manage all activity by users like zooming, moving and rotating. Session manager sends the data to render module which create frames of data and send to encoder using socket communication. Encoder compress frame by video codec and send to client via dedicated stream protocol trough network bandwidth. Quality of video stream, frame rates and stream In case of 2D visualization, some part of image is cropped (shown in fig.) according to the user need which is then encoded to view. Due to the crop technique whole image doesn't download and display on mobile. This technique is good for the high resolution image [14].

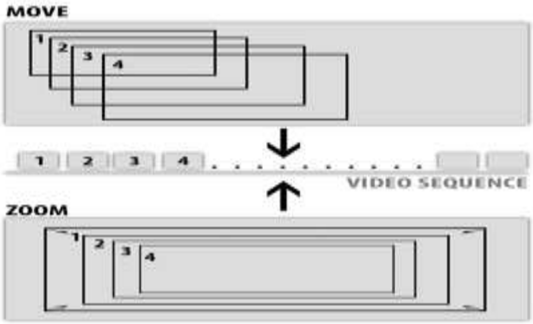

Fig 5. Crop based on user selection

E. Warping:

Panoramic image warping: Spherical panorama performs uniform sampling in every direction and it also allows complete field of view on horizontal and vertical axis. Spherical panorama rendering requires more complex warming computation also requires some equipments and procedures for ad-hoc attainment.

For cubic panoramas the shape where the panorama is projected on is considered as a 3D object with the panorama as its texture. This allows the warping of the panoramic image as a standard 3D rendering, thus utilizing hardware acceleration of current 3D graphic cards [6].

Fix point computation, warping and control algorithm: To speed up the rendering on mobile devices and to improve the computation load floating point calculation is transformed into fixed point computation for 3D warping. Then coordinate conversion is performed with integer calculations and the result is again transfer to fixed point. While performing this task its must to avoid overflow because it requires so much calculations. General 3D transformation is done by using matrix like

$$\begin{pmatrix} Y_1 \\ Y_2 \\ Y_3 \end{pmatrix} = \begin{pmatrix} r_{1,1} & r_{1,2} & r_{1,3} \\ r_{2,1} & r_{2,2} & r_{2,3} \\ r_{3,1} & r_{3,2} & r_{3,3} \end{pmatrix} \begin{pmatrix} X_1 \\ X_2 \\ X_3 \end{pmatrix} + \begin{pmatrix} t_1 \\ t_2 \\ t_3 \end{pmatrix} \Longleftrightarrow Y = RX + T$$

Here R is the matrix for rotation only and translation is denoted by vector T. Each element of R and T has the values in between -1 and 1 because objects are standardizing within unit cubic view volume. To reduce computational cost by finding nearest pixel, scale orthographic projection is used. In this nearest pixel is found by comparing depth value (z value) of numerous pixels those are at same place in warping images. To adjust the splat size i.e. to avoid unwanted hole there is use of control algorithm according to zoom factor. It just checks resolution of target image with the reference image [15].

3D wrapping technique: Image based approach uses 3D wrapping technique to reduce interaction delay. 3D wrapping algorithm needs camera parameters and pixel depth value. In case of OPENGL the camera parameters receive from model view and projection matrix, and the pixel depth values are stored in z-buffer. Wrapping is computed by following formula,

$$(u_2, v_2) = \left(\frac{u_1 a + v_1 b + c + \partial_1 d}{u_1 + v_1 j + k + \partial_1 l} , \frac{u_1 e + v_1 f + g + \partial_1 h}{u_1 i + v_1 j + k + \partial_1 l} \right)$$

In this algorithm next coordinates (u_2,v_2) are calculated from the input pixel of its previous coordinates u_1,v_1. It also uses depth value of pixel u_1,v_1. This algorithm computes each pixel only once. Therefore the complexity of the whole algorithm is proportional to the image resolution. Input image has no pixel to reference when drawing new image such problem is exposure problem. This problem is overcome by selecting two reference image frames and 3D wrapping is used for both frames [16].

F. Optimization:

Static and dynamic optimization: Data compression and content reduction are static optimization techniques those are used to reduce transmission rate by reducing irrelevant and redundant data. Data compression compact the data according to capability of mobile device.

In dynamic optimization according to the mobile device power, proxy server sends additional content to the mobile device. If the mobiles are of low power then VRML proxy server never sends additional content, made file of additional content and then parse that file. VRML Proxy is made in JAVA programming language [13].

For the visualization of complex data on mobile it requires more processing power. Therefore processing consumption task performed at proxy side. To distribute load at client and proxy side, relation between processing power and bandwidth is shown in fig.

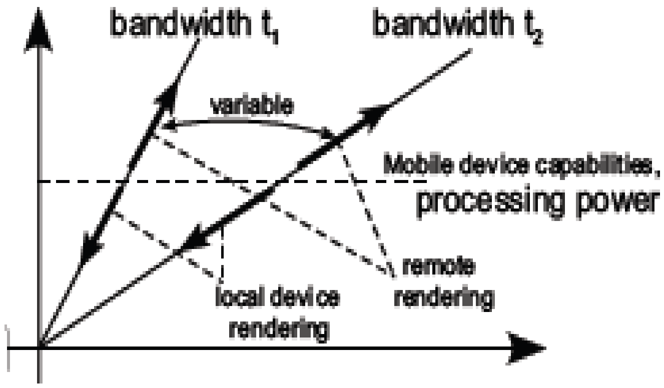

Fig:6 Load Balance.

Dynamic optimization: Common optimization provides static view while the dynamic optimization provides real time rendering of dynamic entities. Culling algorithm is also used to manage dynamic entities by initially deleting them and then adding them into new position. To ensure the scalability of system take out positioning information from client and due to parallel conflicting there is no need to validate client states at server side. Server manages entities by registering subscription. Dynamic entity updates are distributed by fast entities servers using entity proxies [17]. System also provides 3D navigation on mobile.

Optimization techniques: Author [18] provides several optimization techniques for efficient and reliable processing of moving query like lazy query propagation, query grouping and safe period which reduce the processing load at mobile side and also reduce the messaging cost of whole system.

Adoptive synchronization: When the visualization on mobile is performed through wireless network from remote side, a lot of problems may occurs relates to data transmission, bandwidth, frame rates etc. like these energy utilization may also be the problem. Therefore adoptive synchronization method is proposed in [19] which solves the problem of energy consumption and increase transmission speed.

III. OVERVIEW OF PROPOSED VISUALIZATION SYSTEM:

A. Local and Remote visualization: Visualization can be client based only, that can be recognized as local visualization. In case of client based visualization data is store at client and such data then visualized with the help of various techniques. But for local visualization client must have vast storage capacity. However the mobile clients are adversary to this. Therefore remote visualization plays an important role in complex data visualization. Remote visualization can be client-server based or proxy based visualization. Proxy is an intermediary between client and server.

Remote visualization is nothing but visualization on mobile platform. In such case data come from server directly but some time data can transmit from source to destination through server on mobile platform. Here source is nothing but any system on which the input data is stored and destination is any mobile device.

B. Mobile platform: As there is the concept of remote visualization so obviously data traverse through wireless network on various mobile platforms such as Android, Symbian, Windows mobile, J2ME, iOS etc.

Wireless network supports assorted protocols like TCP/IP, FTP, and UDP etc. Some mobile platforms also bear HTTP and TCP communication. Therefore transferring complex data such as images through wireless network on mobile platform is tricky task.

C. Various aspects: Image data transfers through wireless network on mobile platform for the 3D visualization on mobile devices therefore our visualization system considers all following aspects which are responsible for wireless data transmission to achieve maximum frame rates and throughput.

1) Bandwidth: Bandwidth in a networking denotes a network levels. As the bandwidth increases frame might be reduced.

2) Threshold: Threshold indicates the point of outset. It is nothing but a boundaries or given minimum and maximum values. For efficient and accurate filtering it is necessary to set suitable relevance threshold and also for other techniques.

3) Frame rates/ pixel rates: Frame rates measure the frequency with which an image or a frame can be generated by a visualization system. It is measure of smoothness and fidelity.

4) Throughput: Throughput denotes the final result or output. It depends on the device capabilities.

5) Screen and image Resolution: Resolution is a function of image or screen height and width. Considering the mobile device resolution it is difficult to achieve good frame rates and image quality.

IV. COMPARATIVE ANALYSIS OF 3D VISUALIZATION TECHNIQUES:

Techniques discuss above have some advantages and disadvantages those are discuss in Table2 along with their parameters, attributes and aspects.

V. ANALYTICAL STUDY OF MOBILE DEVICES WITH INPUT AND OUTPUT PARAMETERS:

Table3 shows frame rates achieved on specified resolution of related display device particularly in case of remote visualization.

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Table 2: Analysis of 3D visualization techniques

Most constructive techniques in all categories for 3D visualization on mobile	Ordinary pros	Frequent cons	Parameters	Attributes	Aspects
		Remote visualization			
Clustering [1, 2]	1.Increases the number of nodes 2. Rendering time reduces for streaming of size 240x240 3. Increases number of frame rates. 4. A frame rate at client side are the average threshold of 30 fps	1. For the visualization of large resolution, there will be delay in encoding which make real blockage or traffic jam.	-Rendering -Streaming -Encoding -Decoding -Frame rates -Bit rates -Textured polygons and voxels	-Smooth Visualization -Handles packet loss	-Bandwidth, -Exploitation -Latency, -Resources -Frame Buffer
Adoptive [3 7, 4, 20, 21, 22]	1. Provide the appropriate information and fulfill their needs 2. Improve the map's representations with multi-scale, dynamic, interactive characters. 3. selects useful data from huge amount of data, compact and resizes it to display on mobile devices .	1. Complex for spatial and temporal data	-Adaptive factors, -Information filtering, -Context analyzing, -Navigation system, -Context modeling	-Relevance threshold, -Routes, -Point of interest, -Multi scale, -Dynamic and interactive quality, -Relevance threshold, -Routes, -Point of interest, -Multi scale dynamic and interactive quality.	-Map Design, -Selection -Variation in scale -Generalization -Map design,
Filtering [7, 8, 18]	1. Filter useless information and choose user relevant information. 2. Cross filtering works for any unique attribute value. 2. Provides the flexible data abstraction 3. Provides fast and flexible interaction of multidimensional data. 4. Semantic filtering is used for multiple representations with different level of detail.	1. For efficient and accurate filtering it is necessary to set suitable relevance threshold. 2. Relevancy is fuzzy not accurate. 3 Cross filtering requires long sequence and more complex query construction which is beyond the user's capability. 4. Not possible to keep track of query for long time	-Information retrieval, -Information relevancy -Compound and dynamic relevance -Visual abstraction, -Data abstraction, -Attributes and multi scale visualization -Interaction, -Data transformation and design variations.	-Efficiency, -Precision -Route, -point of interest -Level of interest -Dimension and semantic -Flexible data abstraction, -Fast and Elastic interaction	-Threshold, -Scale -Relevant feature and measure -Distance -Time -Detail visualization, - Multidimensional data

Compression [9, 12, 13 23, 24, 25]	1. Provides the depth visualization of 3D model with high quality 2Minimum computation and memory resources 3. Best possible tradeoff between the compression ratio and the visual quality 4. Provides residues packing for efficient compression and provides good quality image for required bandwidth. 5. Good compression quality increases number of frame rates and moving smoothness. 6. View damages compressed better. 7. Create good quality image from compress data. 8. Decreases data transmission rate. 9. For number of simultaneous connected users to single server, compression speed is fast.	1. Increase number of polygons, reduces the compression and smoothness moving capability. 2. Compression algorithm created for hardware can't be change. 3. More polygons may increase transmission rate and cost. 4. Predictive compression does not supports multiple frames 5 If high resolution video stream is considered then it slow down the server.	- Residual image, - Image quality, - Encoder, - Translation - Image resolution -Frame rates -Image quality - Image stream -Remote visualization -Distributed network.	- Compress depth view, - Provide image quality - Motion smoothness, - Reliability - Increase image quality - High frame rates - Decrease network latency	-Frame rates -Image resolution - Bandwidth - Pixels - Threshold -Broadband connection -Screen and image resolution
Warping Techniques [6, 15, 16]	1.To render depth image, 3D warping technique is used 2. 3D wrapping technique to reduce interaction delay. 3 fixed point computation for 3D warping speed up the rendering on mobile devices and improve the computation load	1. Spherical panorama rendering requires more complex warming computation also requires some equipments and procedures for ad-hoc attainment. 2. In fixed point computation avoid overflow because it requires so much calculations	-DIBR, -Scale orthographic projection -Hole filling algorithm, -Residual image -Encoder -Translation -Rotation -Decoder	-Reduce memory use, -Increase rendering speed, -Reduce computation cost -Compress depth view, - Provide image quality	-Memory allocation, -Depth test pixel, Frame, -Pixels, -Distance, -Scaling factors, -Splat size, -Screen resolution
Optimization [13, 26, 17, 18, 27]	1 view 3D virtual reality data on mobile device 2 3 no need to have large storage capacity to mobile device 4 provides efficient and reliable processing of moving query 5 reduces processing load and processing cost of system 6 explore large steam data	1. 3D virtual reality is done by VRML proxy based on JAVA but JAVA gives lower performance as compare to other programming languages.	-Web browser, -Web content, -Semantic content, -Static and dynamic visualization, -Compression and transformation filtering and selection	-Increase browsing capacity, -Reduce latency, -Reduces network bandwidth	-Network Bandwidth, -Mobile Storage Capacity, -Scalability -Local And Remote Rendering

Table 3: Comparative study of mobile devices

Techniques	Input data	Display device	Display device screen Resolutions (pixels)	Configuration of display device	Output Average Frame rates per second
Interactive illustrative visualization [28]	Dataset of 512x512x80 points	Multi field explorer GPU (NVIDIA GeForce GTX 280)	600x600	-------	12 fps
[29] Ghost view interactive technique	3D multimedia data	Intel Pentium 4	------	3.2GHz, 1GB RAM and NVIDIA Quadro NVS 280 PCI-E graphics card	11 to 43 fps
[30] Fish eye view	Web based information	PDA Cellular phone	280 x 320 176 x 220	QVGA, 4gray, 16gray, 256 color, 16bit color etc., WinCE, Palm O/S and many	-------
[31] Magic eye view algorithm	Spheroid	Nokia Series 60, Nokia 7710	280x176, 320x460	----	30 fps
[1] Cluster based rendering	Volume sizes up to a million voxels (that is, 256 x256 x128)	Smart phone, PDA and table PC	240 x 240 512 x 512	Mobile 3D Viewer an ad hoc application using Gtk+ 1.2 and X11 graphics libraries under Linux, tested on HP iPaq H5500 PDAs running Familiar Linux 0.6.1, and on a Compaq T1000 Tablet PC running Linux RedHat 8.0.	30 fps 33 fps
[32] Line based rendering	Scene model of Statue of Liberty, it has 19006 vertices and 37186 faces.	iPAQ 3850 Pocket PC	240x320	16bit color Depth, Windows CE, 802.11b Wireless Network adapter running with a TxRate of 11Mbit	20 fps
[33] Interactive generic algorithm and controller	3D graphics models	PDA, HP iPAQ hx2700	240x320	Microsoft Windows Mobile 5.0 and has a 3.5 inch display; its CPU is Marvell PXA270 processor 624MHz and memory capacity is 512MB.And supports web browser and a 3D viewer	----
[34] Agent Based Modeling Simulation (ABMS) Technology, zooming	3D texture based model	iPAQ 3970 PDA,	---	Linux OS equipped with the GPE x-Windows graphical interface, TCP/IP wireless connection on a Wi-Fi 802.11b network	10-15 frames per second
[13] Dynamic optimization technique	3D virtual reality data	PDA	Bigger	Touch screen, all 4096-65536 colors, Palm, Symbian , Windows, Packet PC, Linux OS	-----
[26] Texture rendering	Pictures of building façade have a resolution of 3008x2000	DELL Axim X50V	640x480	624 MHz ARM processor, RAM memory 64 MB, Intel 2700G GPU and also supports OPENGL ES	2.18 fps and 11.97 fps

[16] 3D warping with zooming and rotation	3D video stream	Nokia N800.	320×240 176×144	TI OMAP2420 330 MHz CPU, 128 MB memory and 802.11g Wi-Fi, Linux based OS	up to 10fps more than 15 fps
[35] 3D multimedia technique with interactive navigation.	Tourist region visualization for multimedia CD-ROMs	PDA (iPAQ of Compaq)	-----	Touch screen, having Garmin GPS	------
[12] Using QoE manager	3D models with 188024 polygons and 33661polygons	Windows Mobile PDA	320x240 pixels	emulator of the Sun Java Wireless Toolkit with GUI, Netbeans IDE,	20 fps (for 188024 polygons), 29 fps (for 33661polygons)
[27] culling and scene graph optimization	3D scene model	Window CE device	---	Multimedia capability, 30.0m resolution ETM color photography , 1.0m resolution color aerial photography (about 3.5 GB), allows programming with C++	----
[24] Predictive compression	Cornell Box with Venus de Milo and reflective sphere (45,109 polygons)	GP2X Linux-based handheld	320 x 240	1Ghz Intel Pentium M with 502MB RAM running Windows XP Tablet Edition.	In between 10-23 FPS
[21] Controller	Streaming interactive multimedia	HTC TyTN II smart phone	288 × 216, 176 × 132 pixels	uses J2ME (Java Micro Edition) to provide flexible environment	25 fps
[15] Fix point computation, warping and control algorithm	Depth image based Angel model	PDA	224x305	-----	9.45 fps
[36] Rendering in point mode	3D jet engine model	Dell Axim x51v PDA	240x320	Intel 624MHz XScale CPU, 64Mb RAM, 16Mb video memory and Microsoft Windows Mobile 5.0.	7.8 fps
[37] 3D visualization using VRML	Face model	Sony Ericsson P800	---	DieselEngine R based, runs on Symbian platform, uses MPEG-4 FBA	10 frames per second
[38] IBR 1) JPEG compression with rotation 2) JPEG compression with translation	Panoramic image with 2048 × 512 size	HP iPAQ 5450 Pocket PC & Microsoft Pocket PC 2002 operating system	320 × 240	Intel PXA250 CPU, 64MB SDRAM for HP iPAQ	1) 14.3 fps (rotation) 2) 7.8 fps (translation)
[39] Rendering on MobiX3D	H-Anim humanoid	Acer n10 and the Dell Axim X50V Pocket	----	624 MHz processor, 64 MB of main memory, an Intel 2700G graphics processor with 16 MB video RAM.	3.9 fps
[40] Real time rendering	Large terrain scenes.	Intel PXA270 Pocket PC 2003	320×240	64 Mb memory with 32Mb RAM & 32Mb ROM, storage with 1GB SD card	8 fps
[14] Interactive video streaming using compression and decompression techniques	Multidimensional Medical datasets	Tablet and cell phone	320x240, 800x480	Equipped with Android 2.2 system.	more than 25 frames per second

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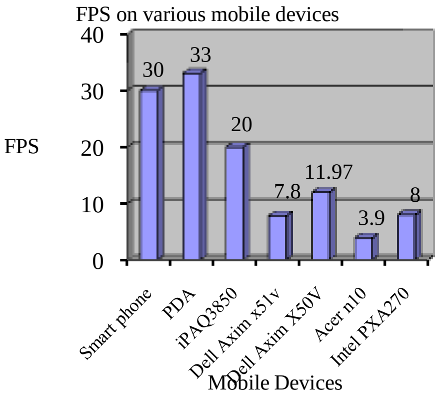
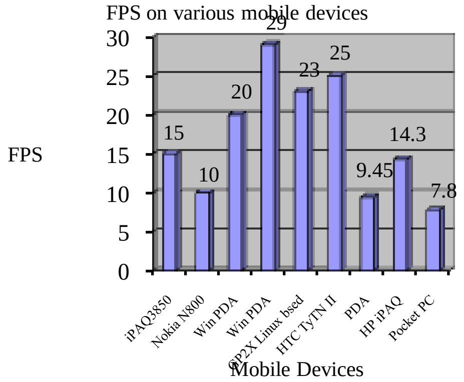
FPS is a very important parameter in case of visualization on mobile devices. Graphical comparison of FPS for different mobile devices is shown as following graphs.



(a)



(b)

Fig 7 (a) Graph for Frames per second obtained from rendering techniques; (b) Graph for Frames per second obtained from remote visualization technique

VI. CONCLUSION

This paper discussed various methods mostly used in remote visualization on mobile devices. In case of remote approach it is found that focus is on data transmission from server to client via wireless network therefore all the methods achieves frames per second by which mobile devices performance comparison is done.

We perform the analytical study of existing visualization techniques in terms of related input and output parameters. It is found that most of the input parameters relates to image data and output in terms of frames per second. From this study it is observed that most of the visualization techniques are implemented on any one different mobile platform. It means one application test for only one mobile platform.

VII. FUTURE SCOPE

Single visualization system can be developed for multiple mobile platforms. Therefore comparative performance analysis of mobile devices can perform using single application. Various techniques can be produce for visualization quality on mobile screen.

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