Application of high performance computing in Markerless Augmented Reality systems

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Abstract—This paper focuses on potential areas of high performance computing utilization within one category of Augmented reality systems – Markerless systems. Initially classification of Augmented Reality (AR) systems is provided. Later on problem areas of marker less AR system are discussed. Towards the end proposal for potential solution is provided.

Keywords—Augmented reality, markerless tracking, GPU computation.

I. INTRODUCTION

These days augmented reality is making it from research labs to everyday life. Application of it to real conditions brings specific requirements to be addressed. This paper aims at providing description where high performance computing system can be utilized within AR system.

Well known taxonomy that addresses concept between real and virtual worlds is based on Paul Milgram [2] and Funio Kishino [2]: Milgram's Reality-Virtuality Continuum. Continuum is visualized as line that is between reality and virtuality. Figure 1 shows continuum based on Milgram definition:

![Fig.1 Milgram’s definition of real to virtual world transition](image)

Augmented reality (AR) system is then system that supplements additional information into real world view. Division of AR systems based on how human observer views added information into real world is:

- Optical see through – semitransparent display is used to display added information to real world view.
- Video see through – real world image is displayed with AR added information. Common setup uses camera – display setup.

According to method how additional information is aligned with real world we recognize these two categories of augmented reality systems:

- Marker based systems – where special markers have to be added to objects and places in real world. AR system then replaces markers with related information in observers view.
- Markerless systems – where AR system needs to identify object and places in real world without using markers. Methods of object recognition with location, orientation and movement information aid are utilized.

Marker based AR system had been developed at DCI FEEI TU Košice in order to research, verify and demonstrate concepts of augmented reality [1]. Specific needs of AR systems for visualization methods were part of studies carried at DCI FEEI and are documented in [3] and [4].
II. MARKER BASED AND MARKERLESS TRACKING

As stated above there are two methods that perform tracking / alignment of real world with virtual objects. Advantage of first method resides in simpler implementation of AR system. Implementation of AR system integration with information system developed at DCI FEEI TU Košice as well as process for creation of marker based AR system is described in [11]. Examples of marker and marker replacement as it happens in AR system developed at DCI FEEI are presented in Figure 3 and Figure 4 respectively.

![Fig.3 Example of marker that indentifies physical object (access card reader) located below marker](image1)

However some shortcomings of marker based AR systems are obvious:

- Need of physical placement of marker on object to indentify it – not possible all the time
- Complex process of marker size and pattern selection for optimal recognition
- Complex process if marker location selection for fast and accurate recognition
- Optical conditions at place of marker can make it difficult for recognition

Markerless tracking represent more generic way compared to marker based systems. Absence of markers in such system increases complexity and that has direct impact on computational needs towards AR system. In relation to Figure 3 marker less AR system has to be able to recognize object in this case access card reader without aid of marker.

High level block diagram of AR system is presented in Figure 5.

![Fig.5 High level diagram of AR system](image2)

*Sensors component* collects information from sensors about environment where observer is located. *Camera* is used as primary data source providing visual information about environment. In case of video see through AR system camera’s image is fed to display. *GPS* has quite important role in case of outdoor systems where it provides continuous feed of observer’s position to AR system. *Inertial* sensors group includes for example accelerometers, gyroscopes and compass and work as aid to determine observer’s position and orientation.

*Processing component’s role* includes:

- process information provided by *sensors component* 
  (perform object detection in images provided by camera, determine and classify observer’s movement and orientation)
- compare recognized objects against object database and align position related data
- align processed information against defined model

Once alignment against model is done such data is provided to *rendering component* whose main role is to render overlay. Such overlay contains information created with AR system in relation to real world image.

High level diagram of AR system on Figure 5 can be extended with another dimension that defines whether system consists of *mobile* part (present with observer) or both *mobile* and *back end* (stationary available via network connection) parts. Having mobile part only has advantage in fast access to required data that is carried along. If there is need to have access to extensive data sets that cannot be placed on mobile part only or performance of mobile part is not satisfactory...
combined solution is used.

With combined solution following split of components can occur:

- sensors component – mobile part only
- processing component – mobile and back end parts
- rendering component – mobile and back end parts

Model definition, position related data as well as object database can be split or rather mobile part contains subset of information that is stored on back end part. Emphasis is on performance of back end due to minimizing response time to mobile part. Large data sets and fast response times lead to high performance computing consideration for back end part.

III. APPLICATION OF HIGH PERFORMANCE COMPUTING IN AR SYSTEMS

Typical set of tasks that is carried within AR system on top of data collected from sensors can be defined as follows:

- Image filtering and adjustment
- Edge detection
- Object / Text / Pattern / Face recognition
- Large data sets scanning / comparison
- 3D computation – 3D model alignment
- Rendering

Nature of tasks above makes then suitable for parallel processing. Approaches for high performance computing are these:

- computational clusters – many individual computers interconnected via high speed network to perform parallel computation
- GPGPU – general purpose computing on graphics processors utilizing many core setup of GPU
- supercomputers – massively parallel specialized computers

Out of abovementioned approaches GPGPU is one that stands out in case of AR systems. Advantage that GPGPU brings is that it can be used in AR systems with mobile part only or in both places for mixed systems where both mobile and back end parts are present. It is possible due to presence of GPU in mobile part that has GPGPU functionality. Currently these frameworks are available for GPGPU computing:

- CUDA – supported by nVidia hardware [7]
- Brook+ - supported by AMD/ATI hardware [8]
- OpenCL – relatively new standard that is adopted by most of major GPU and embedded GPU manufactures [6]

OpenCL standard defines heterogeneous parallel programming on CPU and GPU. With embedded profile [10] it allows to have parallel computations on embedded type of hardware. One of possible setups for combined AR system is displayed on Figure 6. Mobile part of AR system operates on preprocessed data provided from back end part. Back end part has access to full set of data.

![Diagram of combined AR system](image1.png)

In this configuration Processing component combines information from sensors and provides it to Back End Processing component. According to given data Back End Processing component performs image processing and retrieves data related to position as well as executes search of full object database for matching entries. All found information is provided back to processing component of mobile part. That component updates local databases and sends information to rendering component. Back End Processing component determines what additional data shall be retrieved. It will do it based on location and inertial data as well as on knowledge of information that has been already sent to mobile part. These additional data are then provided to processing component of mobile part to update databases. It allows mobile part to have cached data and being able to perform faster. Described process is continuous one.

IV. CONCLUSION

This paper provides view on certain problems of markerless AR systems and points out direction to address them. More detailed work will be carried out to address individual problems – specifically markerless tracking algorithms and solution to implement combined AR system using GPGPU. Research in area of GPU acceleration for rendering and markerless tracking tasks will be carried out. As well as definition of interface between mobile and back end part of combined AR system will be established as part of future research.

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