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Remote raster image browsing based on fast content reduction for mobile environments

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Abstract

Enhanced browsing techniques for digital imagery and small displays facilitate the exploration process of large images often by using new ways to represent the image. Reduction of image content is such an approach mostly linked with need for strong processing power. To overcome this, we propose the use of the Discrete Wavelet Transform (DWT), which inherently separates detail and approximation of the image. By enhancing the detail and removing the approximation directly in wavelet domain, a very fast content reduction can be achieved. Due to its flexibility, JPEG2000 is used as basis for an efficient system for remote image browsing. To satisfy demands which are imposed by the use of current mobile hardware, every stage of the image communication pipeline is adapted and tightly coupled to the used browsing technique to reduce the need for processing power and bandwidth.

Categories and Subject Descriptors (according to ACM CCS): I.3.2 [Computer Graphics]: Distributed/network graphics

1. Introduction

The enthusiasm for mobile computing is still unbroken. Nowadays, the opportunity to handle multimedia data opens new horizons in ubiquitous computing, and services like MMS (Multimedia-Messaging-Service) show that there is a demand for such offers. Nevertheless, handling graphical data is still expensive regarding resources of the mobile device. Especially if large raster images must be processed the system's limitations are quickly reached. Although hardware of mobile devices is steadily improved, the main limitation are still lack of processing power, screen size and resolution, and the costly and slow data transmission.

To overcome the problem of limited screen space, modern presentation techniques for mobile devices have been developed [KRS03b, KRS03a]. For raster imagery the image is often shown in different resolutions to ease the comprehension of the content. Nevertheless, high scaling imposes the problem that image content can only hardly be grasped. Thus, modern approaches reduce the image content in such regions to important structures. While this can be easily accomplished if the content is provided via multiple information layers (e.g. in most Geographical Information Systems, GIS), this can be rather difficult for ordinary raster imagery. One reasonable approach is the modified LargeFocus-Display, shown in Figure 1, where a large image is represented by an interactive focus region in the detail view and a small contour- or edge-map within an overview. Since edges provide most of the content information and are one of the first recognized structures in visual image recognition, the content of the highly scaled detail view is lightened and main information is still kept.

While presenting the focus region is not a problem, the most obvious way to create the edge map might be to use one of the numerous approaches for edge detection, and to scale and display the result. Unfortunately, this is a time consuming process, and if an image must be transmitted before display, most of the costly transferred data is even removed and of little use. That is why we have been searching for alternative ways to accomplish a fast creation of the edge map and to further optimized image compression, transmission and browsing in mobile environments.

The aim of the paper is to show how the different steps in image communication can be combined to form a single strategy to support the interactive display of large imagery on small screens. Here, we want to focus on image handling adapted to the described image browsing technique rather than user interaction. For compression, transmission and efficient reduction of raster image content, we adopt the modern image coding standard JPEG2000. Our approach introduces new concepts for separation and manipulation of image content directly in JPEG2000-domain to decrease the need for computing power and bandwidth. Thereby, the proposed solution is fully compliant to the JPEG2000-standard Part 1 (Baseline) [JPG02] and Part 9 (JPIP) [JPG03]. Regarding image transmission, a much faster display of relevant image content for detail and edge map can be achieved if belonging image data is prioritized during a running transmission. The described system also provides a non-redundant data transfer during the interactive exploration process, where at most the original amount of image data must be handled. To create the edge map, only small portions of the data-stream, instead of the complete JPEG2000-image, are needed, which further reduces the need for bandwidth in remote mobile environments.

Figure 1: *The* LargeFocus-Display *with detail view and reduced image content in overview.*

The paper is structured as follows: After discussing the main idea of the method and related work in section 2, the adaptation and coupling of the different stages of the image communication pipeline are discussed (sections 3-5). To get an impression of the capability of the proposed system and the introduced approaches, achieved results are presented in section 6. Finally, we give a conclusion and directions for further work.

2. Main idea and state of art

Modern image browsing techniques for small displays represent large contents mostly separated in currently interesting and therefore undistorted image regions and additional context information, which is mostly scaled. Thus, not all of the image data is used to achieve a certain image view. The main idea of the paper is to save bandwidth by omitting image data, which is not necessary for the current representation of the image within the browsing technique. Thus, during mobile image transmission, a much quicker image view can be reached.

To achieve this, three different steps in image communication: compression, transmission and browsing are combined into one coupled strategy. It has been shown bei Rauschenbach [Rau99] that such a coupling can save valuable bandwidth during transmission by getting equal visual results at browser side. While this approach was still based on proprietary techniques, another method fully compliant to the modern image coding standard JPEG2000 has been proposed [RT03b]. The approach discussed here moves on this way and additionally reduces the need for bandwidth by introducing new concepts in image representation and handling. Here the reasonable approach to show an edge map instead of the whole image content is used and image communication is adapted to transmit only data which is absolutely necessary to create the detail view and this map at browser side. While for the synthesis of image content belonging to the detail view all available data must be transmitted, this can save further bandwidth especially if the difference between detail and image size is large. To reach this goal the approach introduced here makes use of the following features:

Compression: For efficient transmission raster images must be compressed. There are many compression approaches either for specific data [Gra87], purpose [ISO04] or content [Clu00], but beside its excellent compression performance JPEG2000 provides a number of features for a flexible image handling in compression domain [JPG02]. To consider the different needs for detail and overview, the discussed approach makes use of the opportunity to embed different spatial resolutions within one encoded bitstream. The separated representations of these resolutions are also used to extract and create the edge map at browsing time. Furthermore the feature of random spatial access within the encoded image bitstream is used to separate content for the detail view from the remaining image.

Transmission: The approach makes use of dynamic Regions of Interest (RoI) [RS02, JPG03] for selection and prioritization of separated image regions and resolutions during transmission. Thus, it is possible to transmit data only, which is needed to reconstruct the current focus region and the edge map.
Different approaches for support of static RoIs in JPEG2000 have been proposed [JPG02, GSCE01, WBEB02]. Although they are tightly coupled with the JPEG2000 standard, it is questionable if they can be combined with another interactive image transmission standard, e.g. [Hew97, DI003], to support the dynamic definition and transmission of spatial image regions and resolutions.

Decompression and browsing: By using the provided image browsing technique, a user can explore the image in-

teractively [KRS03a]. Thus, he defines a current focus region regarding his current interests. To provide context for the current detail view, an edge map of the whole image is shown. To create this map rather fast and in appealing quality, portions of the received and still encoded data are selected and enhanced without decoding directly in compressed domain. Furthermore, JPEG2000 provides the opportunity to refine received image data progressively. Thus, data belonging to the detail view and the edge map can be steadily improved during a running transmission.
Although no approach covers the enhancement of an edge map, image manipulation in compression-domain has also been published for general schemes [DL00, DL03] and JPEG2000 [RT03a]. Furthermore, Mallat and Zhong [MZ92] discovered that wavelet decomposition schemes are well suited to detect edges in images and that they can be even similar to the well known canny edge detector [Can86]. Nevertheless, additional and complex analysis is necessary if the canny approach is used, which is costly in terms of computing power.

The next sections are concerned with the application and adaptation of the compression, transmission, decoding and browsing stage to reach the desired reduction of needed processing power and bandwidth in more detail.

3. Compression

JPEG2000 is based on the Discrete Wavelet Transform (DWT) and Embedded Block Coding with Optimized Truncation (EBCOT) [Tau99]. While properties of the first part influence the quality of the edge map, features of the second are related to limited spatial access of the image.

Within a DWT of *k-decomposition stages*, labeled $d = 1,2,\ldots,k$, the image is transformed into $3k+1$ subbands, LL_k and LH_d, HL_d and HH_d. Due to the underlying dyadic decomposition subbands dimensions at stage d, and thus the belonging image *resolution* $r = k-d$, are half the size of stage $d-1$ (cp. to Figure 2). Every subband consists of wavelet coefficients resulting from the transformation of the source signal by wavelet kernels. The baseline standard supports two different transforms, a reversible transform based on 5/3-kernels and the irreversible transform using CDF 9/7-kernels.

The number of decomposition stages and used kernels are of great interest for the embedded image resolutions $r = k-d$ and quality of the edge map. This is due to the DWT which has the property to separate information to sharp content variations, e.g. edges, stored in decomposition stages d, $d < k$, from the approximation of the original image stored in the LL_k-Band.

During the following EBCOT-encoding, each subband is partitioned into *code-blocks*. Spatial random access is possible because each code-block is associated with a limited spatial region and is coded independently. Their bit-streams are collected into larger groupings known as *precincts*. For every image resolution another precinct dimension can be defined. Since the actual code-blocks at each resolution are required to conform to precinct boundaries, precinct dimensions are selected in such a way as to control the spatial influence of code-blocks in each resolution [RT03a]. Thus, precincts form the basis for the prioritization of encoded image data since they contribute to a certain spatial region and resolution.

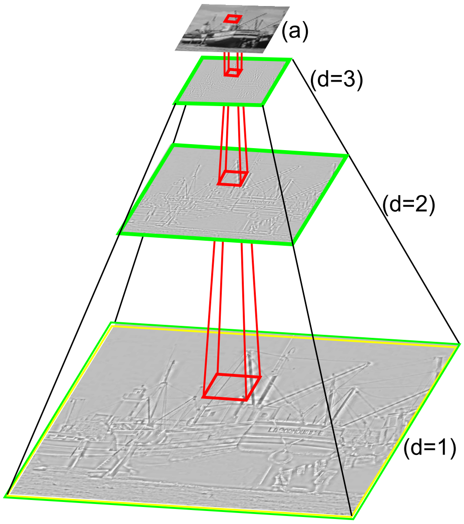

Figure 2: *Separation of approximation (a) and detail ($d = 1,2,3$) within a 3-stage DWT-decomposition: data used for edge map (green) and focus (red). Some data might be omitted during remote image browsing (yellow).*

4. Transmission

In this section, the JPIP-compliant transmission [JPG03] of encoded image data is described, whereby general principles to steer the influence of each precinct in spatial domain as described in [RS02] are applied.

Precincts form also the basis for a dynamic image transmission. They are key structures for the formation of the final bitstream, wherein they can be easily identified. They can be seen as containers for encoded image content from a certain decomposition level. Transmitting precinct data belonging to a certain decomposition level d contributes to the reconstruction of image resolution $k-d$. Thus, if an image should be displayed at a certain resolution r all precincts from decomposition levels $d, d > k-r$ must be considered.

An important property of precincts regarding the support of dynamic RoIs is their spatial limitation. A precinct of size p_1, p_2 at decomposition level d contributes only to a spatial region of size $p_1 \times 2^d, p_2 \times 2^d$ and not the whole image. Thus, a RoI can be supported by transmitting only data from precincts contributing to the spatial region of the RoI. If the RoI changes, other precincts are considered dynamically without influencing remaining or already transmitted precinct data, which is rather flexible in interactive environments. This is also the key for a redundancy free data transmission.

Precincts are also a basic element for image transmission using JPIP. While the first part of the JPEG2000-standard primarily describes the syntax for compliant code-streams, JPIP is an evolving standard for efficient interactive communication of JPEG2000-encoded content.

Since one of the main goals of JPIP is also to exploit the spatially random access properties of JPEG2000, to standardize a means of interacting with the data in an efficient and effective manner for client-server based applications, it is well suited to support the selected access of image content. The communication between client and server consists of high-level request/response pairs, where data can be stored and decoded from a cache structure at client side. As we will see in the following section, this approach is rather useful for the support of the detail view and the creation of the edge map.

A main principle used in JPIP to partition code-streams, are *data-bins*. Data associated with such a structure can be truncated and transmitted in different ways. Data-bins are linked to precincts in a way as to provide a data-bin for every precinct. Thus, the described principle of dynamic RoIs can be easily combined with a compliant JPIP-transmission.

5. Decoding and browsing

While the interactive image browsing mostly consists of user-driven movements of the RoI and resulting client requests for this new region, we want to focus on the decoding step which plays the most important role within the introduced interactive image browsing system.

All image data arriving at client side is stored in a client cache, where in the described approach certain data is also copied to an edge cache used for contour map creation only. The decoding itself consists of two different parts: providing image content for the detail and the overview.

To provide the user with a preview of the image data during a still running and often slow transmission, the ability of JPEG2000 to progressively refine image content in quality is used. This is done by a piecewise transfer of belonging precinct data from JPIP data-bins. Since every piece can be added and fully decoded with previously received pieces, the accuracy of precinct data, and thus of detail and edge map, increases progressively during a running transmission.

5.1. Providing image content for the detail view

The detail view consists of a certain image region displayed at full resolution and quality. This is necessary to provide a user with all the information available for its current interest (cp. red pyramid in Figure 2). To keep the signalling overhead during interactive exploration as small as possible, automatic region-requests contain only information to size and position of the current RoI and will only be sent as long as the image has not fully been received. The server then selects and transfers all precinct data which contributes to this region and which has not already been transmitted. Thus, a non-redundant data transmission paired with an adapted data transfer can be achieved. Data available for the RoI is decoded directly from the client cache and updated at certain time steps to support the feature of a progressive image refinement. To decrease the computational efforts, we use the feature of JPEG2000 to limit the decompression of image data to precinct data contributing to the current focus region only, which can be a substantial advantage if the image is rather large.

5.2. Providing image content for the overview

The overview consists of the scaled version of an edge map of the image. While for the current RoI all belonging data must be transmitted to get the best representation of the image within the detail view, only selected data is needed to create the edge map. Here the server must consider two different points to decide which data must be transmitted: (1) the scaling factor of the overview and (2) image data needed to create the edge map.

To take the scaling of the overview into account, only image data up to a certain embedded image resolution is transferred. This is reasonable, since data from higher resolution levels does not further refine the scaled view or is even removed during the scaling procedure. Since the amount of data increases with every transmitted resolution, such an approach saves a lot of costly bandwidth.

Furthermore, even if the transmission is limited to a certain resolution r, not all data from decomposition levels $d, d \geq k - r$, contributing to the reconstruction of this resolution is needed to create the desired edge map. Edges are lines with a sharp variation mostly located at the boundaries of important image structures. The idea for a fast and efficient creation of an edge map is to use properties of the DWT as part of the JPEG2000-encoding pipeline, more precisely the separation of detail and approximation of an input signal. Thus, we focus on data from decomposition levels which have been filtered with an detail preserving high band filter ($d < k$), since they mainly keep edge and sharpness information of the image (cp. decomposition levels $d = 1, 2, 3$ in Figure 2). These decomposition levels are part of a compliant JPEG2000-bitstream, and thus, it is not necessary to apply further edge detection algorithms to the image, but to do an ordinary decoding of this data only. By doing so, we save processing power needed for additional edge detection and further bandwidth, since only certain decomposition levels must be considered and transmitted.

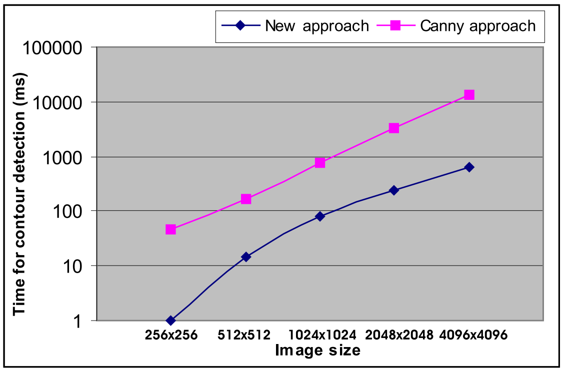

Figure 3: *Time needed for transcoding (new approach) vs. edge detection (canny approach).*

Nevertheless, further steps are necessary to enhance the visual quality of the map, since ordinary decoding leads to problems with weak edges. As a starting point, belonging precinct data from the determined decomposition levels $d, k - r \leq d < k$, is stored in a formerly empty edge cache. After decoding this high-pass filtered data, they might visually perish in averaged energy (cp. decomposition levels $d = 1,2,3$ in Figure 2), since they often have low altitude and variance. To emphasize the distinction between background and edges, we propose a fast method to modify the approximation LL_k of the image with appropriate data directly in wavelet domain. This step alters the edge cache in that manner as to fill all cache positions for precinct data from resolution LL_k with related data from a second bitstream. This bitstream was created at client side by encoding a single colored image, to enable a consistent backdrop of the map. To get a large difference between backdrop and edges, pure white is used.

As for the detail view, the edge cache containing now all information for an appropriate edge map is decoded and updated periodically to consider incremental data for belonging decomposition levels. Thus, a progressive preview of the edge map can be also provided.

A great advantage of the proposed method turns out if data transfer for the detail view is considered again. Although for RoIs all encoded data must be transmitted, for the current region it is only necessary to transmit data belonging to the original approximation and higher resolutions. Most of the data for lower resolutions has already been transmitted to provide support for the edge map and is already stored within the client cache. Thus, every packet is only transferred once, and again a non-redundant image transmission is achieved even if current RoI and edge map are handled separately in different cache structures.

6. Discussion and results

In this section we discuss the performance of the proposed approach, regarding the main influencing factors: need for processing power and bandwidth and quality of the edge map. For our measures, we use grey-scaled images of different size, all encoded with same parameters and the JPEG2000-toolkit KAKADU [Kak04]. The spatial influence of all precincts has been set to 32×32 which offers a good trade-off between access and encoding performance [RS02].

One of our aims was to develop an approach, which needs only low computational power for edge map creation to satisfy demands of mobile devices. Since transcoding the encoded image content by a selective transmission of certain image data is rather fast due to the built-in random access feature of JPEG2000, the approach is quite competitive with regard to conventional approaches as shown in Figure 3. For our comparisons, we use the well known canny edge detector (cp. section 2). The results are obtained by measuring the time needed for transcoding and enhancing vs. edge detection only, since decoding and displaying takes nearly same time for both methods. The proposed method is up to 20 times faster, since only fast copy operations are performed. Contrary, the canny approach uses complex matrix operations, which need quite a lot of computing power.

Nevertheless, beside the improvement of processing speed the produced quality of the edge map is also of particular importance for the evaluation of the method. As shown in Figure 4, the visual result produced by the discussed approach is more detailed and not as rich in contrast as the canny approach, which has only be developed for this purpose. This might be an disadvantage in very bright environments, where maximal contrast a crucial demand. Nevertheless, during our user tests we did not come across with such problems. The achieved results still satisfy the requirement to adequately represent the image content within the overview (cp. Figure 1). If one further considers the fact that as long as basic attributes of the content are kept, presentation speed dominates the quality of the overview, the approach is rather appropriate especially for hardware with low processing power, e.g. mobile devices.

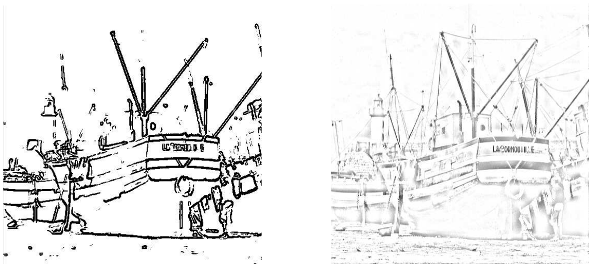

Figure 4: *Edge maps scaled by a factor of 8 created by the canny edge detector (left) and the proposed approach (CDF 9/7-kernels, $k = 6$) (right).*

The number of decomposition levels k is of crucial interest with regard to image quality, since with increasing k more information is kept in all subbands $d < k$. Beyond a certain value this even increases the need for bandwidth. Nevertheless, with increasing k the scaling of the overview can be much better approximated by one of the embedded resolutions. We tried images of different size and content, and got very nice visual results as well as small bitstreams by using a value of $k = 6$.

Another point influencing the quality of the edge map are the used wavelet-kernels. We conducted a number of experiments and found that CDF 9/7-kernels achieve the best visual results (Figure 5). Due to the larger influence of the kernels, they are not as sensitive to noise and produce much more steady-going contour lines than the 5/3-kernels, which are more accurate and unsteady. Thus, a much smoother representation can be achieved if using 9/7-kernels.

Figure 5: *Edge map in higher resolution created by the proposed approach (CDF 9/7-kernels, $k = 6$).*

The compression performance regarding the resulting size of the bitstream plays an important role if the often expensive and slow transmission of imagery via mobile channels is taken into account. Here again the number of decomposition levels and the used wavelet-kernels influence the performance of the approach. Due to the lossy encoding bundled with the 9/7-kernels, they produce the most compactly encoded data. An appropriate number of resolution levels mainly depends on particular image content, but a number of $k = 5$ is often stated to be a good value to start with. Fortunately, this coincides with the number of decomposition levels, where best quality of the edge map has been achieved.

Since the edge map must be scaled by factors $v : h$, much content is removed. Thus, the approach reduces the number of levels d needed to create a meaningfully scaled edge map. Starting with level k, we found that at least $(k - s + 1)$ levels, with $s = min(v,h)$ and $s \leq k$, must be transferred (cp. Figure 2). Due to the reason that the amount of encoded image information on subbands increases exponentially with decreasing d, we can assume the amount of all image data to be $\sum_{i=0}^{k} 2^{2i}$. Thus, $\frac{\sum_{i=1}^{k-s+1} 2^{2i}}{\sum_{i=1}^{k} 2^{2i}}$ of the bandwidth needed for all levels $d, d < k$, is saved if the first (s-1) decomposition levels are omitted while transmitting data for the creation of the edge map. This value can be even more increased if multi-component imagery is considered. Here, only image data from one suitable component, e.g the Y-component for images transformed to the YUV color system, must be transmitted to create the overview. Data from other components is only transferred to provide full detail for the spatially rather small focus view.

Compared with conventional approaches, the advantage of an JPEG2000-based transmission becomes even more apparent, since traditional edge detection must be applied to the complete image. Instead of transmitting all data, for the proposed method at most data belonging to decomposition levels $d, d < k$, must be transferred. However, to achieve an exact reconstruction of the current RoI, all data contributing to the synthesis of this spatial region must also be transmitted. Assuming this region to cover a 10^{th} of the image size, an increment of only $\frac{1}{10} + \sum_{i=k-s+2}^{k} \frac{2^{2i}}{10}$ must be added to the amount needed to create the edge map, and much bandwidth (e.g. 89% for $k = 6, s = 4$) is saved, although the image appears as completely transmitted within the current browser representation.

Another huge advantage of the discussed approach is the ability to refine the RoI as well as edge map progressively. This is of great importance since during image transmission a content preview can be given. We found, after only half of the data from belonging precincts has been received, the preview of the edge map is already rather good. This significantly decreases the time needed until first browsing interactions can be performed. Regarding conventional approaches, it is questionable if edge detection methods can be used on the often rather blurred preview data. Furthermore, ordinary edge detection must be executed after every progression step to consider newly received data, which further increases the need for processing power.

7. Conclusions

This paper presents an approach for efficient image browsing of large raster images by adapting and combining the different stages in image communication to the interactive image browsing technique LargeFocus-Display. Thus, much bandwidth and even processing power can be saved. Thereby, the system is fully compliant to the modern image coding standard JPEG2000 and exploits properties of the DWT as integral part of the codec. Thereby new approaches to support the creation of an edge map as lightened image representation for the highly scaled overview are introduced. Rather than applying a conventional edge detector in pixel-domain, the map is created by extracting and enriching relevant information directly in wavelet domain. Thus, the proposed method is much faster than conventional strategies, since no further operations are necessary. Best results are achieved by using 6 decomposition levels and CDF 9/7-kernels. Our results show, the approach is well suited for efficient remote image browsing via mobile channels, since a substantial amount of bandwidth can be saved by limiting the transmission of image details to certain regions (focus region) and decomposition levels (edge map).

Although, we focused on the application of the principle in a fully compliant JPEG2000-system, the idea can also be applied to other DWT-schemes. Here it might be interesting to leave the JPEG2000 specification and to explore the properties of other wavelet kernels and decomposition schemes. Further work might also lead to the creation of other image browsing systems, since every browsing technique has its own characteristics and ways to show the image.

References

[Can86] CANNY J.: A computational approach to edge detection. *IEEE Transactions on Pattern Analysis and Machine Intelligence* (1986).

[Clu00] CLUNIE D. A.: Lossless compression of grayscale medical images - effectiveness of traditional and state of the art approaches. In *Proceedings of SPIE MI* (2000).

[DI003] DICOM - Digital Imaging and Communications in Medicine, Base Standard PS 3.1, 2003.

[DL00] DRORI I., LISCHINSKI D.: Wavelet warping. In *Proceedings of 11th Eurographics Workshop on Rendering* (2000).

[DL03] DRORI I., LISCHINSKI D.: Fast multi-resolution image operations in the wavelet domain. In *IEEE Transactions on Visualization and Computer Graphics* (2003).

[Gra87] GRAPHICS INTERCHANGE FORMAT (TM): A standard defining a mechanism for the storage and transmission of raster-based graphics information.

[GSCE01] GROSBOIS R., SANTA CRUZ D., EBRAHIMI T.: New approach to jpeg2000 compliant region of interest coding. *SPIE 46th annual meeting, Applications of Digital Image Processing* (July 2001).

[Hew97] HEWLETT PACKARD, LIVE PICTURE AND EASTMAN KODAK: *IIP - Internet Imaging Protocol*, 1997.

[ISO04] ISO/IEC 15948:2004: Information technology – computer graphics and image processing – portable network graphics (png): Functional specification.

[JPG02] *JPEG 2000 image coding system, Part1*. Final Publication Draft, ISO/IEC JTC 1/SC 29/WG 1 N2678, 19 July 2002.

[JPG03] *JPEG 2000 image coding system, Part9*. Final Committee Draft, ISO/IEC JTC 1/SC 29/WG 1 N3052R, 7 August 2003.

[Kak04] KAKADU, a comprehensive, heavily optimized, fully compliant software toolkit for jpeg2000 developers. Version 4.2, http://www.kakadusoftware.com/, 2004.

[KRS03a] KARSTENS B., ROSENBAUM R., SCHUMANN H.: Information presentation on mobile handhelds. In *Proceedings of IRMA2003* (May 2003).

[KRS03b] KARSTENS B., ROSENBAUM R., SCHUMANN H.: Visual interfaces for mobile handhelds. In *Proceedings of HCII2003* (Crete/Greece, June 2003).

[MZ92] MALLAT S., ZHONG S.: Characterization of signals from multiscale edges. In *IEEE Transactions on Pattern Analtsis and Machine Intelligence* (1992).

[Rau99] RAUSCHENBACH U.: The rectangular fisheye view as an efficient method for the transmission and display of large images. In *Proceedings of IEEE-ICIP'99, Kobe, Japan* (1999).

[RS02] ROSENBAUM R., SCHUMANN H.: Flexible, dynamic and compliant region of interest coding in JPEG2000. In *Proc. IEEE ICIP2002* (Rochester, N.Y., September 2002).

[RT03a] ROSENBAUM R., TAUBMAN D. S.: Merging images in the jpeg2000 domain. In *Proceedings of VIIP2003* (September 2003).

[RT03b] ROSENBAUM R., TAUBMAN D. S.: Remote display of large raster images using jpeg2000 and the rectangular fisheye-view. In *Journal of WSCG* (February 2003), Skala V., (Ed.), vol. 11, UNION Agency, pp. 387–393. ISSN 1213 - 6972.

[Tau99] TAUBMANN D.: High performance scaleable image compression with ebcot. *Proceedings of IEEE International Conference On Image Processing 3* (August 1999), 344–348.

[WBEB02] WANG Z., BANERJEE S., EVANS B., BOVIK A.: Generalized bitplane-by-bitplane shift method for jpeg2000 roi coding. In *Proc. IEEE ICIP2002* (Rochester, N.Y., September 22-25 2002).