Darius MATEIKA

ANALYSIS OF THE ELECTRONIC SYSTEM DEDICATED FOR SHARED CREATION AND USAGE OF SPECIALIZED DOCUMENTS

Summary of Doctoral Dissertation
Technological Sciences,
Electrical and Electronic Engineering (01T)

1552-M

VGTU LEIDYKLA TECHNIKA

Vilnius 2008

VILNIUS GEDIMINAS TECHNICAL UNIVERSITY

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Darius MATEIKA

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General characteristic of the dissertation

Topicality of the problem. Information amounts in modern society are consistently growing. In such conditions only well timed and precise information can assure successful activity. Organizations are dealing with information from external sources and information circulating internally. It is very important to organize internal information flow effectively, especially for large organizations having lots of departments and employees.

Under the ideal circumstances every addressee must receive required information at the right moment of time. Otherwise somebody will be forced to suspend his activity and wait for that information. There will be a downtime. Downtimes increase cost of the production, raise projects’ implementation risks and decrease organizations competitive ability.

Such problems are being solved using various document management solutions. The first document management systems (DMS) only allowed simplifying document search and interchange. Coming of digital signature, which in many countries is already legally equal to the traditional signature, allowed using fully electronic documents, without paper versions. This allowed simple and cheap interchange of electronic documents, minimized paper document storage problems.

Documents are the main communication mean in the organization. Documents allow departments, responsible for different functions, to cooperate in developing the final product. Documents are the vehicles of business processes and documents constitute a major part of organizational memory. It is logical that when the connection between a document and a business process is so tight – DMS were supplemented with business process automation and management functions. Sending business process information jointly with document, allows having information about the task to be performed with the document in the right place at the right moment.

During DMS evolution the definition of the document has been widened. In modern DMS document can be: a several byte length data set, a traditional electronic document, an image of scanned paper document, a voice memo, photograph image, video material or any other type of computer data format. Removed document type restrictions expanded DMS application range. General purpose document management systems today are already high developed and it become possible to apply them in specialized environment.

The most important task to be solved before applying DMS in the specialized environment is to adapt system for operation with specialized data. Even if DMS do not divide documents by types and all types are treated evenly, specialized documents can have larger than usual size, can be complicated to load or represent them and etc.

So, it is important to identify which DMS features are most essential to adjust for managing specialized documents and which new features are required to make system operational in the new environment.

Aim and tasks of the work. The aim of this dissertation is to investigate the performance of specialized image compression, propose a method or a combination of methods most suitable for storage and transmission of specialized images, develop algorithms for automated registration of such images. The following tasks must be solved to achieve the purpose:

1. Investigate the performance of specialized image compression when applying methods usual for DMS and usual specialized systems, evaluate applicability of these compression methods for specialized image storage and transfer.
2. Propose techniques for automated large image formation where large images are stitched from several smaller fragments and the calculations of stitching parameters are based on both artificial markers and image features.
3. Create corresponding algorithms and experimentally investigate the properties of the techniques.

Scientific novelty. The following results were obtained during PhD studies which are relevant in the science of electrical engineering and electronics:

1. Proposed technique for the evaluation of image quality.
2. Investigated applicability of image compression methods for compressing medical, aerial and general purpose images.
3. Created technique and corresponding algorithm for the fully automatic stitching of two-dimensional computer radiographs. Algorithm is based on the requirement to have additional information about scale and rotation angle in the image fragments to be stitched. After stitching, additional artificial information is removed without leaving any distortion.
4. Created technique and corresponding algorithm for automated creation of large photomap images, where fragment superposition is based on general features in overlapping fragment area.

Methodology of research. The following methods and techniques were used in the work: Fourier spectrum analysis, correlation like methods, elements of mathematical morphology, geometrical elements.

Approbation of the dissertation. The results of the thesis were announced in 8 Lithuanian and international conferences in Lithuania and Poland. There were also printed 7 scientific papers: 2 of which are in journals referred by Information Sciences Institute (ISI) databases (Thomson ISI Web of Science), 2 papers in journals referred by other accredited by Lithuanian Science Council databases, 1 is printed in the international, reviewed conference proceedings and 2 are published in other conference proceedings.

Practical value. The obtained research results may be used to adopt DMS storage and data transfer modules for operation with specialized images. Proposed large image formation algorithms may be implemented as new DMS functions.

Defended propositions

1. The best applicable image compression method for images where distortions are not acceptable is JPEG LS, method allows achieving average compression ratio 1:2, image maps must be used to reduce transfer time.
2. When large images are created by stitching several smaller, low contrast fragments, artificial markers having rectangular shape must be used.
3. When large images are created by stitching several smaller fragments, containing small objects, the most rational is applying Harris–Plessey method supplemented with the predictive value of threshold function. Multiple fragment overlapping is mandatory condition for this method.

The scope of the scientific work. The thesis consists of general characteristic of the dissertation, four chapters and general conclusions. Lists of references and author's publications are presented after conclusions.

The volume of the work is 114 pages without annexes; there are 31 formulas, 49 figures and 7 tables used. The list of references contains 105 records.

Content of the dissertation

1. Analysis of the special purpose document management systems. The chapter covers an analysis of existing publications related with problems of the thesis. There are presented review of document management system evolution and applications in specialized environments. Review of image compression methods, image quality evaluation methods and their suitability for measuring quality of compressed images. Finally, there is analysis of methods for large image formation where large image is stitched out of several smaller fragments. Chapter is ending by conclusion and formulation of the thesis objectives.

2. Analysis of image compression methods. In the modern information management systems image compression storages meet dual and contradictory requirements. Content of the images must be saved with minimal information loss and highest compression ratio because of a big size.

This chapter describes the search of compromise solution to identify the image compression method giving highest compression ratio and smallest image information loss. For this purpose it is proposed to compare compression methods using mean exponential error criteria. During analysis selected image compression formats are analyzed experimentally. Identified and proposed the most appropriate, for the medical and aerial images, compression solution.

Proposed image compare method detects even smallest compression errors. The method gives two possible outcomes. Numerical value, for expressing image similarity in numbers and error map, for describing which image regions are compressed with biggest error. Error map helps to analyze image compression specific. Error is calculated according to this equation:

$$D = \frac{1}{X}\frac{1}{Y}\frac{1}{C}\sum_{i=1}^{X}\sum_{j=1}^{Y}\sum_{k=1}^{C} \mathrm{e}^{\left|A_{ijk} - A_{gijk}\right|}; \qquad (1)$$

where: D – mean exponential error, X – image width, Y – image height C – number of color bands, A_{ijk} – intensity of the pixel ij in the color band k from the original image, A_{gijk} – intensity of the pixel ij in the color band k from the compressed image.

Quality measure calculated according to equation (1) was used in the compression quality evaluation experiment. Compression methods, common for DMS and specialized systems, were used to compress medical, aerial and general purpose images. The results of the experiment where medical, aerial and general purpose images were compressed using all evaluated compression methods showed, that the highest compression ratio in the category of lossless compression was detected in the images compressed with JPEG LS. In the category of lossy compression, the highest image quality was detected in images compressed using JPEG 2000, but only in case where compression ratio is higher than 5.

Medical images have a lot of regions where intensity is changing slowly or even have a constant value. This feature is determined by medical equipment. Images are generated digitally and information is concentrated only in part of the image. From the image compression error map, it is visible that biggest compression error values are located in the image parts with quickly changing intensity. Fig 1 and Fig 2 represents a medical CT image and its error map. According to Fig 2, such regions are compressed without errors even when lossy compression methods are used. This explains why all evaluated image compression methods gave the highest compression ratios and quality measures when compressing medical images.

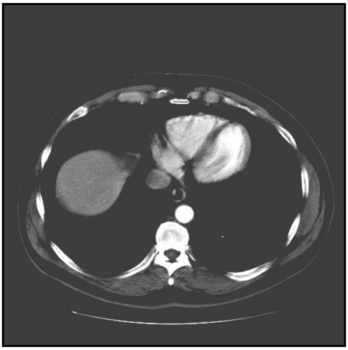

Fig 1. Example of medical CT image

Fig 2. Example of the medical image's error map

Error map of the aerial images showed opposite results. Entire error map area indicates high error rates. This explains why all evaluated image compression methods gave the lowest compression ratios and worst quality measures when compressing aerial images.

In medical applications image distortion is not acceptable. This limitation sets the requirement to use lossless compression only. According to the results of the analysis, images stored in lossless JPEG LS can achieve compression ratios up to 1:2. Transferring such images can take undesirably long if the bandwidth of the channel is low. Solution of the problem can be transferring of the lossy compressed image map. Requirements for the quality of image map are low. The ratio reaches 1:50 there. The image map allows user selecting required region of interest which should be transferred lossless first of all. Performing in such way, most important information can be transferred faster, but excess data must be transferred over transmission channel.

Amount of excess data can be reduced by using differential image method. Lossy compressed images are looking very similar to original, even when compression ratio is 1:30. Such images contain information, which is already transferred to the user. It would be logical to transfer only rest part of image information after sending image map. Usual image compression methods do not allow such functionality, anyway it is possible to use information from transferred image map when sending lossless compressed original image. In this case instead of original lossless compressed image after sending image map, differential image must be sent. Differential image should be calculated according to equation:

$$A_{sijk} = \frac{I_m}{2} + \left(A_{ijk} - A_{gijk}\right); \quad (2)$$

where: A_{sijk} – intensity of the pixel *ij* in the color band *k* in the differential image; A_{ijk} – intensity of the pixel *ij* in the color band *k* from the original image, A_{gijk} – intensity of the pixel *ij* in the color band *k* from the compressed image; I_m – highest possible image intensity value.

Compression of differential image instead of original gives higher compression ratio, but not always. Experiment represented in Fig 3 shows, that higher overall (lossless image + image map) compression ratio by differential image method is granted only in limited range of image map's compression ratio.

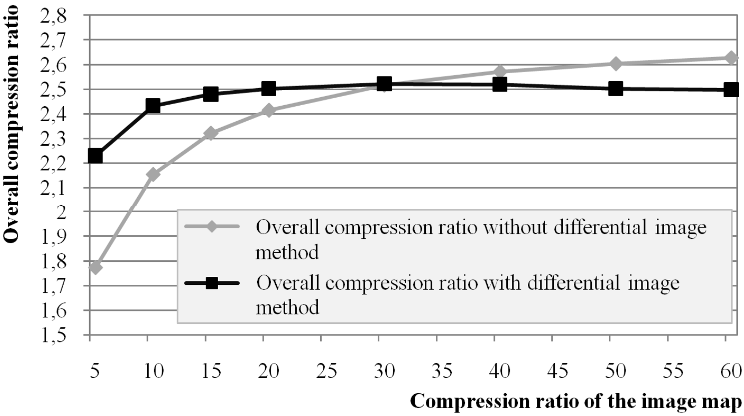

Fig 3. Efficiency of differential image method

Fig 3 shows, that differential image method is efficient only when compression ratio of the image map is lower than 30 and these result are valid only tested image set. Differential image allow removing up 50% of image map's excess information, but the amount of removed information is different for every picture.

3. Large image formation using artificial markers. There are a lot of cases where large images can be created only by stitching several smaller images.

Image stitching allows creating panoramic images 135°×200° with a usual photo camera 50°×35°. Because of the photo detectors' resolution limitations, photomap image must be registered by stitching big number of smaller images. When acquiring large paper documents possibility to scan them is limited by scanner dimensions. In the modern medicine, today, it is usual to employ computer diagnostic methods. In large size X-ray image registration, essential limitations are brought by the cost of the equipment, directly related to its complexity and size.

In radiography stitching, fragments only have a very small overlapping area, are noisy and might not contain any relevant structure within the overlapping area. Such conditions makes feature based radiograph stitching unreliable and forces to use area based stitching methods. Area based methods have two principal limitations. Reference and sensed images must have identical or at least statistically dependent intensity functions. From the geometric point of view, only shift and small rotation between the images are allowed. For removal of second limitation it is proposed to use artificial markers, allowing unification of scale and rotation angle before calculation of fragment disposition.

Proposed technique requires artificial markers to be interposed into the fragments. Artificial marker should: be easily and precisely detectable, allow calculating stitching parameters, allow calculating the value of every parameter independently from other parameters and allow removing them from the image without leaving any distortions.

For medical X-ray image stitching listed requirements could be met by a metal (or other material sensitive to the X-ray radiation) strip containing rectangular holes, placed near the object being registered. The shape of the strip is shown in the Fig 4.

Fig 4. Shape of the proposed artificial marker strip

The strip should be placed near the object, which should be registered, as it is shown in the Fig 5. After image registration and stitching operations the strip can be removed from the image without any subsequences. Metal objects in the X-ray images always have higher, than human body parts, intensity. This means, that strip can be easily detected in the image by using threshold function.

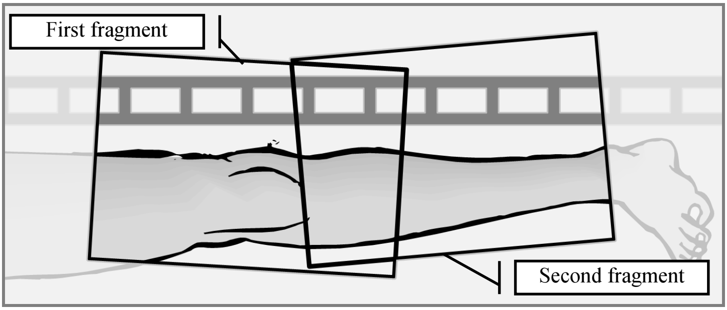

Fig 5. Fragment registration process

To detect the rotation angle in fragments with artificial markers it is enough to detect rotation angle of the rectangle from the strip shape. For detection of fragment's rotation angle, proposed to calculate Fourier transformation of the rectangle, detected in the strip shape. Image of the rectangle detected in the digital X-ray image (256×256 8 bit gray) rotated by 35° angle is shown in the Fig 6. It's centered spectrum – Fig 7.

The spectrum image has four clearly visible branches. Two of them, the brightest ones, have the same rotation angle as the rectangle itself. So, the image rotation angle can be identified by detecting the rotation angle of the described branch. This is done by converting image to the polar coordinate system and summarizing spectrum coefficients according to angle. Result of such calculation is represented in the Fig 8. In the Fig 8 it is clearly visible that highest peak corresponds to rotation angle of the brightest branch in this figure.

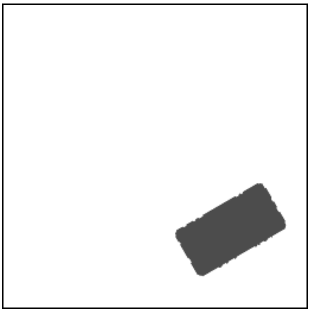

Fig 6. Detected rectangle

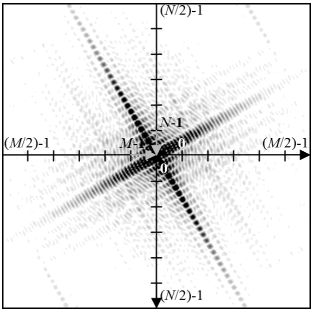

Fig 7. Centered spectrum of the detected rectangle

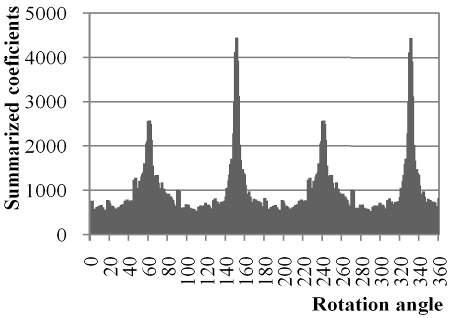

Fig 8. Fourier spectrum coefficients summarized according to angle

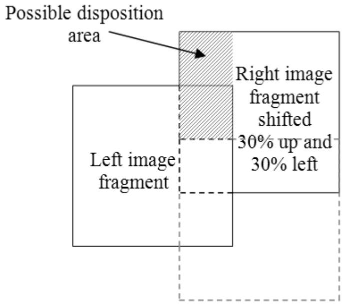

Fig 9. Possible fragment disposition area

Fragment scale is proportional to the area of detected strip rectangle. In the Fig 6, there are only two intensity levels. One of them represents the rectangle, other – the background. To calculate the area of the rectangle, all pixels representing its intensity must be calculated. Performing fragment scale unification, areas of the each rectangle in each fragment should become equal.

Image fragment disposition is determined using calculation of the normalized cross correlation coefficients for all possible disposition points. This step can be performed only when fragments have the same scales and rotation angles. Search area is determined by the registration conditions. When maximal fragment overlap and maximal misalignment in vertical axis are limited to 30%, possible disposition must be searched in the area represented by Fig 9.

Finally, when the superposition parameters are identified, fragments can't be just placed one on another, because after such operation a visible seam will appear in the stitched image. Seams can be removed with blending operation. Blending extends stitching line through the whole overlapping area and stitching consequences becomes hardly noticeable.

4. Large image formation using general image features. Photomap images do not contain objects which presence in their content could be predicted. Such images are very miscellaneous, they do not contain objects with a priori known form or parameters. There are no means to complement them with such information. Feature points in such images can be based only on the most general image characteristics. When it is required to identify feature points in two–dimensional space the most appropriate are corner detection algorithms. Lots of modifications of such algorithms exist in our days. They differ in accuracy, detection rate, localization, repeatability rate, robustness to noise, speed and etc.

Most of corner detection algorithms have high repeatability rate, but are sensitive to changes of image rotation angle, and scale and other geometrical transformations. It is proposed to minimize possibility of such transformations by using specifics of photomap image fragment registration.

The procedure for merging several smaller photomap image fragments into one big image can be described with these steps: selection of the detector's position, image acquire, determination of the image parameters, parameter adjustment and image stitching.

The position of the detector depends on its movement trajectory, speed and the time moment. Images must be superposed before stitching. Superposition requires having overlapping area in both images. Time interval between registering two image fragments depends on the required size of overlapping area and the speed of the photo detector. The easiest way to explain how it depends on the detectors speed is an example. If images are being acquired with photo detector having 10 mega pixels, aspect ratio 4:3 matrix and required image resolution is 3 pixels per meter, then the length of the area covered by the image will have length approximately 900 meters. Such length can be easily defined by changing altitude and view angle parameters. Moving photo detector with speed 100 m/s (what corresponds to 360 km/h) and demanding 20% overlap, time period between registrations according to (3) will be ~7.2 s.

The example shows, that time period between acquire of images is quite long and it can be even prolonged by slowing down aircraft's speed. Modern photo detectors are capable to register an image in shorter, than one second time period. This consideration allows much higher than 20% image fragment overlap. Bigger overlapping area allows more precise and reliable fragment superposition.

Multiple overlapping allows analyzing the same interest point in several overlapping images, comparing them, rejecting distorted ones and etc. Registering images as fast as they can be analyzed makes them very similar each to other. Small details in the aerial image, in the reality are huge objects. Little changes in the image correspond to large displacements in reality which simply cannot happen in a part of the second. The most important advantages of shortening time interval between fragment registrations are similarity of fragment rotation angle and scale parameters.

When image fragments have very similar scale and rotation angle, Harris-Plessey corner detection method gives high repeatability rate and is well suitable for corner point detection in such images. To detect corner points using Harris–Plessey method following steps must be performed:

Fig 10. Original image

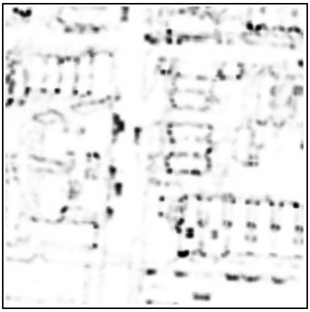

Fig 11. Cornerness map

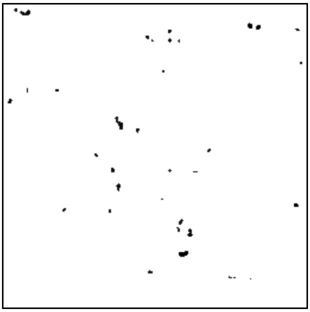

Fig 12. Cornerness map after threshold function

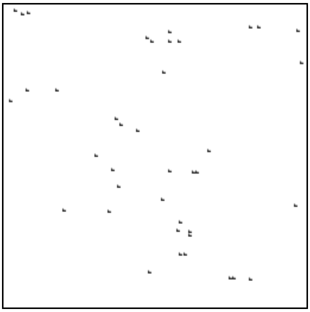

Fig 13. Detected corner points

1. Calculate the cornerness map for the image. The result of this calculation is an image, where corner areas are having brighter, than the flat areas, intensity. Fig 10 represents the original image, Fig 11 – its cornerness map.

2. Apply a threshold function on the cornerness map. After this, corner areas are separated into isolated regions. The result of threshold function is presented in the Fig 12.

3. Calculate local maximums in the isolated corner regions obtained in the step two. These maximum points will be the searched corner points. The map of the detected corner points is presented in the Fig 13.

The number of detected corner points depends on several detection parameters. The most important parameter is the value of the threshold's function. Threshold function applied on the cornerness map, rejects image regions, where corner measure is smaller than the threshold value. How many regions will be rejected depends on the chosen value and the content of the image. It is most important to avoid two extremities:

1. If chosen threshold value will be too high, most of image regions with good corner response will be eliminated and there will be too less corner points detected.

2. Choosing too low threshold value will result detection of false (having weak corner response) corner points. In this case, it would be hard to match the same corner points in two image fragments.

Objective is to choose threshold value allowing corner point detection algorithm to detecting only these corner points, which can be easily matched. This means that corner detection process must be controlled. Using the same threshold value for corner detection in several fragments gives different counts of corner points detected in these fragments. Results of such experiment are shown in Fig 14. In this chapter it is proven, that the count of the detected corner points can be controlled by selecting the right value of the threshold function. Threshold's value must be calculated according to image area, which will be left unaltered after threshold operation. Threshold's value calculated according to unaltered area can be calculated using histogram of the cornerness map. Fig 15 shows that the number of detected corner points linearly depends on the image area unaltered by the threshold operation. Ordinate axis in Fig 15 represents the number of detected corner points and abscissa – the relative area of image pixels unaltered by threshold function expressed percents.

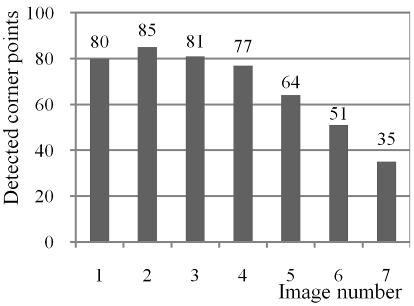

Fig 14. The counts of the detected corner points in test images, when threshold for all of them had fixed value

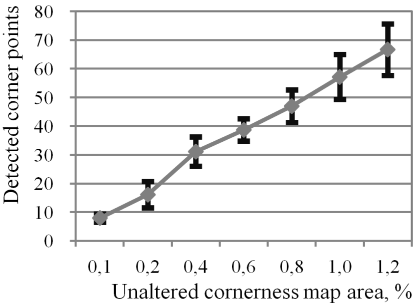

Fig 15. The counts of detected corner points when threshold values were calculated for every image individually

Relative area of unaltered pixels isn't the indicator which directly determines the number of corner points identified in the image when it is processed by Harris-Plessey algorithm, but it shows that connection between these two parameters is linear and strong: The differences in the numbers of detected corner points in the sample images now is less than 20%, when fixed threshold value gave differences larger than 100%. This means that calculating threshold‘s value from image‘s histogram allows to control the number of detected corner points.

General conclusions. The aim of dissertation was to investigate the performance of specialized image compression, propose a method or a combination of methods most suitable for storage and transmission of specialized images and develop algorithms for automated registration of such images. The main results are the following:

1. It was proven, that the best applicable image compression method for images where distortions are not acceptable is JPEG LS. Method allows achieving average compression ratio 1:2. Image maps must be used to reduce transfer time.
2. The method for comparing of images was created for the evaluation of image compression performance. Proposed method evaluates even the smallest compression errors. The method gives two possible outcomes: numerical value – for objective image quality evaluation, and error map – for describing which image regions are compressed with the biggest error. Error map allows to analyze image compression particularity.
3. The results of the image compression analysis showed, that the highest compression ratio and the best quality were detected in the images having a lot of regions where intensity is changing slowly or even have a constant value. Most of images created with medical equipment have regions with constant intensity. This explains why all evaluated image compression methods gave the highest compression ratios and quality measures when compressing medical images. The results of the analysis, where medical, aerial and general purpose images were compressed using all evaluated compression methods showed, that the highest compression ratio in the category of lossless compression was detected in the images compressed with JPEG LS. In the category of lossy compression, the best image quality was detected in the images compressed using JPEG 2000, but only when compression ratio is higher than 1:5.
4. In medical applications image distortion is not acceptable. This limitation sets the requirement to use lossless compression only. According to the results of the image compression analysis, images stored in lossless JPEG LS achieves average compression ratio 1:2. Transferring such images can take undesirably long if the bandwidth of the channel is low. Solution of the problem is transferring the lossy compressed image map prior to transferring original image. The ratio reaches 1:50 there. The image map allows selecting required region of interest which should be transferred lossless first of all. Performing in such way, most important information is transferred faster, but excess data must be transferred over the transmission channel. Amount of the excess data can be

reduced by using differential image technique. The technique allows removing up to 50% of excess information.

5. It was proven, that for fully automated registration of large, low contrast medical images into DMS, large images must be created by stitching several smaller image fragments. Stitching of such image fragments requires having artificial markers registered together with image fragments.

6. It was proposed to interpose artificial markers, having rectangular shape, when large medical X–ray images are created by stitching several smaller fragments in fully automatic manner. Such markers allow fully automated detection of fragment's rotation angle, scale and disposition. Fragment disposition must be calculated only after scale and rotation angle were unified in all of the image fragments. Easiest way to detect the fragment's rotation angle is to calculate the spectrum of the rectangular hole in the shape of the metal strip. Scale can be detected by calculating the area of rectangular hole. The disposition is identified by calculating correlation coefficients in all of the probable disposition points.

7. It was proven, that for fully automated registration of large images containing small, high contrast details into DMS, large images also must be created by stitching several smaller image fragments. This category of images does not allow using artificial markers for fragments' superposition. It is required to analyze general image features to make image fragments' superposition possible.

8. It was ascertained, that accurate and reliable image fragment stitching, based on general features, is possible only when image fragments' overlapping is multiple. Most suitable for stitching two-dimensional image fragments general features are corner points in the image content. When fragment superposition is based on corner points, the count of corner points must be controlled. It was proven, that Harris-Plessey corner detection method, supplemented with the predictive value of the threshold function is well suitable for corner detection in such images.

List of Published Works on the Topic of the Dissertation
Publications referred by Information Sciences Institute (ISI) databases:

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3. Mateika, D.; Martavicius, R. 2007. Analysis of the compression ratio and quality in aerial images, *Aviation* 4(11): 24–28. ISSN 1648-7788 (Compendex).
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SPECIALIOS PASKIRTIES DOKUMENTŲ BENDRO KŪRIMO IR NAUDOJIMO ELEKTRONINĖS SISTEMOS TYRIMAS

Mokslo problemos aktualumas. Šiuolaikinės visuomenės informaciniai poreikiai auga milžiniškais tempais. Tokiomis sąlygomis tik tiksli ir laiku gaunama informacija gali garantuoti sėkmingą veiklą. Tačiau sėkminga organizacijos veikla nėra susijusi vien tik su iš išorės ją pasiekiančia informacija apie rinkos būseną, konkurentų planus ir artimiausias šalies ekonomikos kitimo tendencijas. Labai svarbus yra efektyvus informacijos cirkuliavimas organizacijos viduje. Tai ypač aktualu didelėms įstaigoms, turinčioms daug padalinių, kuriose dirba daug darbuotojų.

Didėjant aktualios informacijos kiekiui, visą šį informacijos srautą reikia valdyti. Idealiu atveju visi darbuotojai turėtų gauti jiems skirtą informaciją būtent tuomet kai ji yra reikalinga. Kitu atveju kažkas tos informacijos turės laukti ir negalės atlikti tolimesnių darbų, o tai jau prastova. Prastovos didina produkcijos savikainą, didina projektų įgyvendinimo riziką, mažina organizacijos konkurencingumą.

Problemų sprendimui taikomi įvairūs dokumentų valdymo sprendimai. Dokumentų valdymo sistemų (DVS) atsiradimas, leido supaprastinti dokumentų paiešką ir perdavimą. Sistemoms tobulėjant atsirado galimybė dokumentus pasirašyti elektroniniu parašu, kuris daugelyje valstybių jau yra įstatymiškai prilygintas tradiciniam parašo variantui. Tai sudarė galimybę apskritai atsisakyti įprastų, popierinių dokumentų laikmenų ir paversti juos elektroniniais. Popierinių dokumentų pakeitimas elektroniniais leidžia išvengti jų saugojimo milžiniškuose archyvuose.

Dokumentai yra pagrindinė organizacijų komunikavimo priemonė. Dokumentų dėka skirtingas organizacijos funkcijas vykdantys padaliniai gali bendradarbiauti kurdami galutinį produktą. Dokumentai yra verslo procesų transportas ir visa organizacijos atmintis. Esant tokiai glaudžiai sąsajai tarp organizacijos verslo procesų ir dokumentų, natūralu kad dokumentų valdymo sistemoms yra priskiriamos ir verslo procesų organizavimo funkcijos. Proceso automatizavimo informacija siunčiama kartu su dokumentu, tokiu būdu atsiranda galimybė dokumentą reikiamu momentu turėti reikiamoje vietoje su papildoma informacija, ką su juo reikia daryti. Taip valdomi tiek dokumentų srautai, tiek su jais susiję darbo procesai.

Dokumentų valdymo sistemoms tobulėjant buvo panaikinti apribojimai dokumento formatui. Moderniose DVS dokumentu laikoma tiek vos kelių bitų apimties duomenų seka, tiek tekstinis dokumentas, tiek vaizdinė ar garsinė medžiaga, arba bet koks kitas kompiuterinis duomenų formatas. Apribojimų dokumentų tipams panaikinimas išplėtė DVS taikymo sritis. Atsirado galimybė DVS panaudoti srityse, kuriose anksčiau buvo naudojamos unikalios, konkrečiam uždaviniui spręsti pritaikytos sistemos.

Norint DVS panaudoti specialios paskirties srityse svarbiausias uždavinys yra sistemos pritaikymas darbui su specializuotais duomenimis. Net jeigu šiuolaikinės DVS ir neskirsto dokumentų į tipus, visiems galioja ta pati apdorojimo koncepcija, būtina atsižvelgti į tai, kad specializuoti dokumentai gali būti žymiai didesnės nei įprastiniai dokumentai apimties, gali būti sudėtinga ar nepatogu juos įvesti į sistemą, gali kilti atvaizdavimo ir kitų problemų.

Taigi, yra svarbu nustatyti, kurios DVS savybės yra labiausiai tobulintinos taikant sistemas specializuotose terpėse, kokios būtų naudingos papildomos funkcijos darančios sistemą pilnaverte naujoje aplinkoje.

Darbo tikslas ir uždaviniai. Šio darbo tikslas ištirti specialiosios paskirties vaizdų glaudinimo galimybes, parinkti tokių vaizdų saugojimui ir perdavimui tinkamiausią formatą arba jų derinį, sudaryti algoritmus automatizuotam didelių specialiosios paskirties vaizdų įvedimui ir tuos algoritmus ištirti. Pagrindiniai darbo uždaviniai yra šie:

1. Ištirti specialiosios paskirties ir dokumentų valdymo sistemoms įprastųjų vaizdų glaudinimo metodų tinkamumą specializuotų vaizdų saugojimui ir perdavimui.
2. Pasiūlyti specialios paskirties vaizdų automatizuoto sudarymo apjungiant keletą mažesnių fragmentų metodus, pagrįstus dirbtinių žymių įterpimu ir sutapdinimu pagal bendrąsias savybes.
3. Sudaryti pasiūlytų metodų algoritmus ir eksperimentiškai ištirti jų galimybes.

Mokslinis naujumas. Rengiant disertaciją buvo gauti šie elektros ir elektronikos mokslui nauji rezultatai:

1. Pasiūlytas metodas glaudintų vaizdų kokybės vertinimui.
2. Ištirtas glaudinimo formatų tinkamumas medicininių, aviacinių ir bendrojo pobūdžio vaizdų glaudinimui.
3. Sukurta metodika automatizuotam medicininių rentgeno vaizdų fragmentų apjungimui. Pasiūlytas ir ištirtas jos algoritmas pagrįstas dirbtinai į fragmentus įterptų sutapdinimo žymų panaudojimu.
4. Sukurta metodika automatizuotam fotožemėlapių vaizdų sudarymui iš mažesnių vaizdo fragmentų. Pasiūlytas ir ištirtas jos algoritmas pagrįstas apjungiamų fragmentų sutampančiųjų vaizdo dalių bendrųjų savybių panaudojimu.

Tyrimų metodika. Darbe panaudoti klasikinės spektrinės analizės metodai, koreliaciniai metodai, vaizdų matematinės morfologijos elementai, geometriniai metodai.

Praktinė vertė. Gauti vaizdų glaudinimo tyrimų rezultatai gali būti panaudoti DVS dokumentų saugykloms ir dokumentų perdavimo moduliams adaptuoti darbui su specializuotais dokumentais. Sukurti didelių vaizdų sudarymo iš mažesnių fragmentų algoritmai gali būti įdiegti dokumentų valdymo sistemose, kaip naujos automatizuoto įvedimo funkcijos arba esamų funkcijų patobulinimas.

Ginamieji teiginiai

1. Vaizdų, kuriuose iškraipymai yra neleistini, glaudinimui geriausiai tinka JPEG LS glaudinimo metodas leidžiantis pasiekti vaizdų vidutinį glaudinimo santykį iki 1:2, o vaizdų išsikvietimo pagreitinimui reikia naudoti vaizdo žemėlapius.
2. Didelių, mažo kontrastingumo vaizdų sudarymui iš fragmentų būtina naudoti dirbtines žymas, turinčias stačiakampės formos kiaurymes.
3. Automatizuotai sudarant didelius vaizdus iš fragmentų su smulkiais, kontrastingais objektais racionaliausia taikyti *Harris–Plessey* metodą papildytą prognozuojama slenksčio funkcijos verte. Kad metodas veiktų, fragmentai turi būti registruojami su daugkartiniu persidengimu.

Darbo apimtis. Disertaciją sudaro įvadas, ketveri skyriai, rezultatų apibendrinimas, literatūros ir publikacijų sąrašai. Taip pat yra priedas, kuriame atspausdinti tyrimuose naudoti vaizdų pavyzdžiai. Papildomai sudaryti disertacijoje dažnai naudojamų žymėjimų bei santrumpų sąrašai.

Bendra disertacijos apimtis yra 114 puslapių, neskaitant priedų, tekste pateikta 31 numeruota formulė, 49 paveikslai ir 7 lentelės. Rašant disertaciją buvo remtasi 105 literatūros šaltiniais.

Įvade nagrinėjamas problemos aktualumas, formuluojamas darbo tikslas bei uždaviniai, aprašomas mokslinis darbo naujumas, pristatomi autoriaus pranešimai ir publikacijos, disertacijos struktūra.

Pirmasis skyrius skirtas literatūros apžvalgai. Jame pateikta dokumentų valdymo sistemų raidos ir jų taikymo darbui su specializuotais dokumentais apžvalga, aptarti medicininiuose įrenginiuose ir dokumentų valdymo sistemose populiariausi vaizdų saugojimo formatai, vaizdų glaudinimo kokybės vertinimo algoritmai ir jų tinkamumas įvairių tipų vaizdų kokybės vertinimui, didelių vaizdų sudarymo apjungiant mažesnius fragmentus metodai. Skyriaus pabaigoje pateikiamos išvados ir formuluojami disertacijos uždaviniai.

Antrajame skyriuje pateiktas medicininių, aviacinių ir bendrojo pobūdžio vaizdų glaudinimo santykio ir kokybės tyrimas. Skyriaus pradžioje aprašomas pasiūlytas glaudinimo kokybės vertinimo algoritmas, kokybės vertinimo eksperimentas ir aptariami jo rezultatai. Nustatomas tinkamiausias tirtų vaizdų saugojimui ir perdavimui glaudinimo metodas, pateikiami eksperimentiniai vaizdų perdavimo, naudojant dvejopą glaudinimo metodą, rezultatai.

Trečiajame ir ketvirtajame skyriuose tiriamos automatizuoto didelių vaizdų sudarymo apjungiant keletą mažesnių fragmentų galimybės. Pasiūlytos metodikos bei algoritmai vaizdų su stambiomis detalėmis apjungimui panaudojant dirbtinai įterptas sutapdinimo žymes ir vaizdų su smulkiomis detalėmis apjungimui panaudojant bendrąsias vaizdo savybes.

Rezultatų apibendrinimas. Disertacijoje buvo siekiama ištirti specializuotuose dokumentuose esančių vaizdų saugojimo ir perdavimo DVS galimybes bei sukurti automatizuoto vaizdų įvedimo metodikas. Darbo metu gauti šie rezultatai:

1. Įrodyta, kad vaizdų, kuriuose iškraipymai yra neleistini, glaudinimui geriausiai tinka JPEG LS glaudinimo metodas, leidžiantis pasiekti vidutinį vaizdų glaudinimo santykį 1:2, o vaizdų iškvietimo pagreitinimui reikia naudoti vaizdo žemėlapius.
2. Glaudinimo efektyvumo tyrimui buvo sukurtas vaizdų kokybės palyginimo metodas, įvertinantis net mažiausias vaizde esančias klaidas. Taikant pasiūlytą metodą pasiekiamas dvejopas rezultatas. Skaitinė vidutinės eksponentinės klaidos vertė leidžia kiekybiškai palyginti su praradimu glaudinančių algoritmų į vaizdą įnešamą klaidą. Klaidų pasiskirstymas vaizde – klaidos žemėlapis, leidžia stebėti, kuriose vaizdų srityse atsiradusi nesuvidurkinta eksponentinė klaida yra didžiausia. Vaizdų žemėlapis leidžia visapusiškai analizuoti vaizdų glaudinimo specifiką.
3. Analizė parodė, kad geriausiai glaudinami vaizdai, kuriuose yra daug sričių su lėtai kintančiu arba pastoviu intensyvumu. Tokiomis savybėmis pasižymi medicinine įranga gauti vaizdai. Atlikus vaizdų glaudinimo tyrimą nustatyta, kad be praradimo glaudintuose vaizduose didžiausias glaudinimo santykis, vidutiniškai 1:2, gaunamas vaizduose, glaudintuose JPEG LS metodu. Su informacijos praradimu glaudintuose vaizduose geriausia kokybė yra JPEG 2000 metodu glaudintuose vaizduose, bet tik tuo atveju, kai glaudinimo santykis didesnis už 1:5.
4. Nustatyta, kad medicininiais įrenginiais gautus vaizdus reikia glaudinti tik be informacijos praradimo glaudinančiais algoritmais. Be praradimo glaudintų vaizdų glaudinimo santykis nedidelis, vidutiniškai 1:2. Jie perduodami lėtai ir tai trukdo bendrojo naudojimo darbą realiuoju laiku. Vaizdo perdavimui greičiau nei 10 s reikia naudoti vaizdo žemėlapius. Dideliu glaudinimo santykiu glaudintas vaizdo žemėlapis leidžia pasirinkti vaizdo sritį, kuri turi būti siunčiama pirmiausiai. Taip sudaroma galimybė anksčiau pradėti vaizdo analizę. Perteklinės informacijos kiekis, naudojant vaizdo žemėlapius, sumažinamas pritaikius skirtuminio vaizdo metodą. Metodas veiksmingas tik ribotame vaizdo žemėlapio glaudinimo santykių diapazone. Skirtuminio vaizdo

metodas leidžia pašalinti iki 50 % dėl vaizdo žemėlapio perdavimo atsirandančios perteklinės informacijos.

5. Įrodyta, kad mažo kontrastingumo didelių vaizdų, sukuriamų medicininiais įrenginiais, įvedimui į DVS taikytinas vaizdo fragmentų apjungimo į vieną didelį vaizdą metodas. Tokių vaizdų sudarymui iš fragmentų būtina naudoti kartu su vaizdu sukuriamas dirbtines žymas.

6. Pasiūlyta medicininių rentgeno vaizdų fragmentų automatiniam apjungimui į vaizdą įterpti dirbtines žymas – metalinę juostelę su stačiakampėmis kiaurymėmis. Tokios, į registruojamo vaizdo fragmentus įterptos, žymos sudaro galimybę automatiškai nustatyti vaizdo fragmentų posūkio kampą, mastelio skirtumus ir tarpusavio perstūmimą. Fragmentų tarpusavio perslinkimo nustatymo operacija turi būti vykdoma tik po mastelių ir posūkio kampų vaizdo fragmentuose suvienodinimo. Vaizdo fragmentų posūkio kampai geriausiai nustatomi analizuojant dirbtinių žymų juostos stačiakampių kiaurymių spektrus, mastelių skirtumai palyginami pagal stačiakampių žymų plotus. Tarpusavio perslinkimas nustatomas pagal persidengiančioje fragmentų srityje apskaičiuotus tikėtino perslinkimo koreliacijos koeficientus.

7. Įrodyta, kad didelius vaizdus su smulkiais ir kontrastingais objektais įvedant į DVS taip pat taikytinas vaizdo fragmentų apjungimo į vieną didelį vaizdą metodas. Tokių vaizdų sudarymui iš fragmentų dirbtinės žymos netinka, būtina analizuoti vaizdo fragmentų turinį ir nustatyti charakteringuosius bruožus.

8. Nustatyta, kad tikslus ir patikimas vaizdo fragmentų apjungimas pasirėmus charakteringaisiais bruožais galimas tik, kai fragmentai persidengia daug kartų. Tinkamiausi, vaizdo fragmentų apjungimui, charakteringieji bruožai yra vaizde esantys kampai. Atliekant vaizdo fragmentų sutapdinimą pagal kampų taškus pritaikytas *Harris–Plessey* metodas. Taikant šį metodą būtina valdyti fragmente aptinkamų kampų taškų skaičių, todėl *Harris–Plessey* metodą reikia papildyti prognozuojama slenksčio funkcija.

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ANALYSIS OF THE ELECTRONIC SYSTEM DEDICATED FOR SHARED CREATION AND USAGE OF SPECIALIZED DOCUMENTS

Summary of Doctoral Dissertation
Technological Sciences, Electrical and Electronic Engineering (01T)

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