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Imaging Navigation Aiding Destroying Focal Liver Lesions

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Abstract

Article presents methodology of computer aided destroying focal liver lesions using imaging navigation system. Methodology allows generation of personalized anatomical model of patient's liver based on computer tomography screening with contract media of abdominal cavity, registration of edited anatomical model relative to real patient's position on operation block, presentation of surgical tools position during treatment on the liver's anatomical model and non-direct monitoring of ablation process of focal lesions. Liver anatomy model comprises organ's and focal lesions' surface and central lines of vascular structures in liver. Generation of personalized patient's model has been verified based on anonymized abdominal cavity computer tomography with contrast media screening cases. It gives an ability of manual correction of results and planning of entry point, target point and surgical tool trajectory. Registration of patient's position happens in two stages: stiff registration using Horn algorithm and non-stiff registration using deformation field based on splines. During treatment, position of ablation needle on anatomical liver's model is visualized and ablation process is monitored through presentation of graphs of process' electrical parameters: among them are electrical tissue resistance around ablation needle, momentary power and total energy delivered by power with radio frequency generator to liver's parenchyma.

Keywords: ablation of liver tumours, image navigation, personalized model of liver's anatomy, computer aided diagnostics and therapy

Introduction

Primary and metastatic liver tumours make an significant challenge for contemporary medicine. Additional difficulty in destroying focal liver lesions is big organ's movability during breathing, which is an effect of the fact that liver is adjacent to diaph. Organ displacements can reach a few centimetres, which causes target point to displace [6]. Among available techniques of destroying focal liver lesions there are resection techniques – the most effective ones and ablation techniques applied in cases where resection techniques can't be used [8]. Imaging navigation systems aids treatments performance through presentation of treatment run on a spatial patient's anatomy model [1,2]. Model's task is to show the most important anatomical structures from the performed treatment point of view, target point and surgical tools positions visualization on anatomical model. Nowadays in clinical practice imaging navigation systems are commonly used for treatments using stiff human body skeleton's elements as referral points, for example: skull's bones, spinal cord's elements etc. Imaging navigation of parenchymal organs is more challenging due to lack of fixed referral points.

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Goal

Study goal is to present prototype of system which aids minimal invasive treatments of destroying focal liver lesions.

Material and Methods

After literature studies , simulation and pilot studies methodology of aiding of destroying focal liver lesions focused on ablation techniques were proposed, especially electrical ablation with radio frequencies were considered. Methodology consists of few stages:

1. Preparation of personalized patient's anatomy model
2. Treatment planning
3. Registration of patient's position during treatment in comparison to pretreatment patient's anatomy model
4. Operation field visualization during treatment and ablation process monitoring

Preparation of Personalized Patient's Anatomy Model

Presented methodology is based on anonymized computer tomography abdominal cavity screenings with contrast media. Based on computer tomography images the following are found: liver's surface, vascular structures and volume of focal liver lesions. Details on used segmentation methods were presented in the articles [5,9,10,11]. Building of personalized patient's model requires point inside liver parenchyma and one point for each focal lesion. Vascular structures finding does not require indication of points on liver's images. After indication of mentioned starting points personalized, anatomical liver's model is generated automatically.

Treatment Planning

To plan treatment personalized anatomical patient's liver model, presented in previous point, is used. Author has proposed a method of presentation of anatomical liver's model in the way suitable for treatment's planning. Model's presentation using selected layered DICOM images (2D presentation of selected cut of the volume) and presentation of the whole volume of abdominal cavity (volumetric imaging – 3D) is possible. Liver's outline and focal lesions are presented in the form of organ's surface cuts corresponding to specific DICOM images. There is a possibility to manually correct segmentation results. Vascular structures are presented in the form of central lines using smooth splines which are also manually correctable. Presentation of segmented structures on layered images of abdominal cavity allows to evaluate resectability of lesions and to select entry point, target point and surgical tool trajectory (figures: correctable 2D image, correctable vascular image, 3D tumour image).

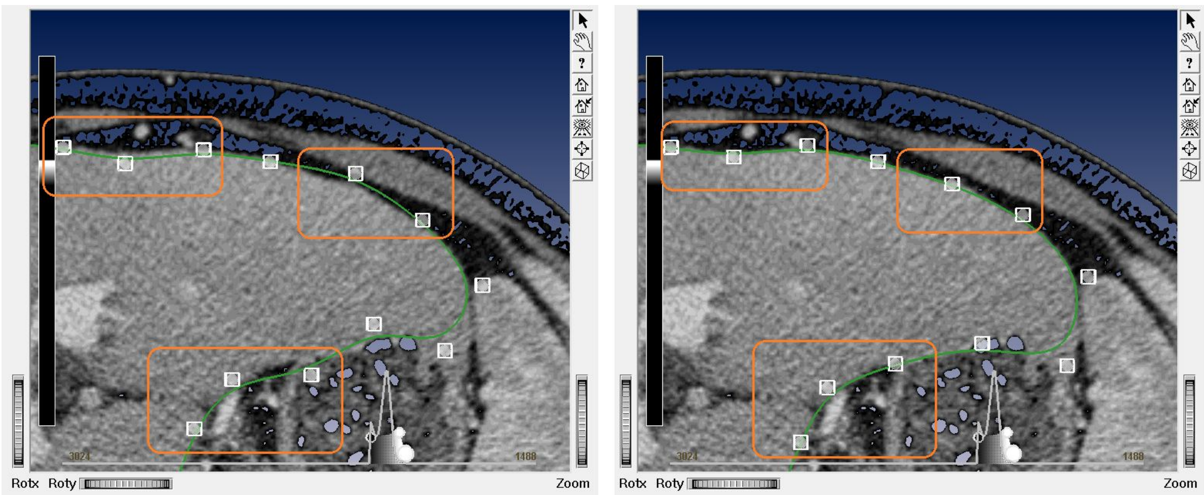

Fig. 1: Liver Model Evaluation: Before Correction – Left, After Correction - Right [5]

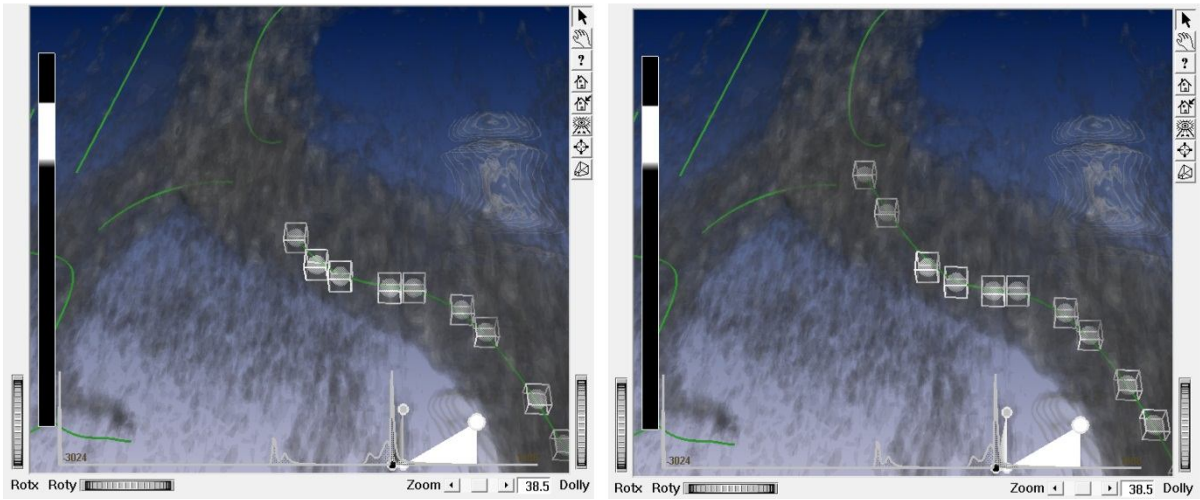

Fig. 2: Vessel Skeleton Evaluation: Before Correction – Left, after Correction - Right [5]

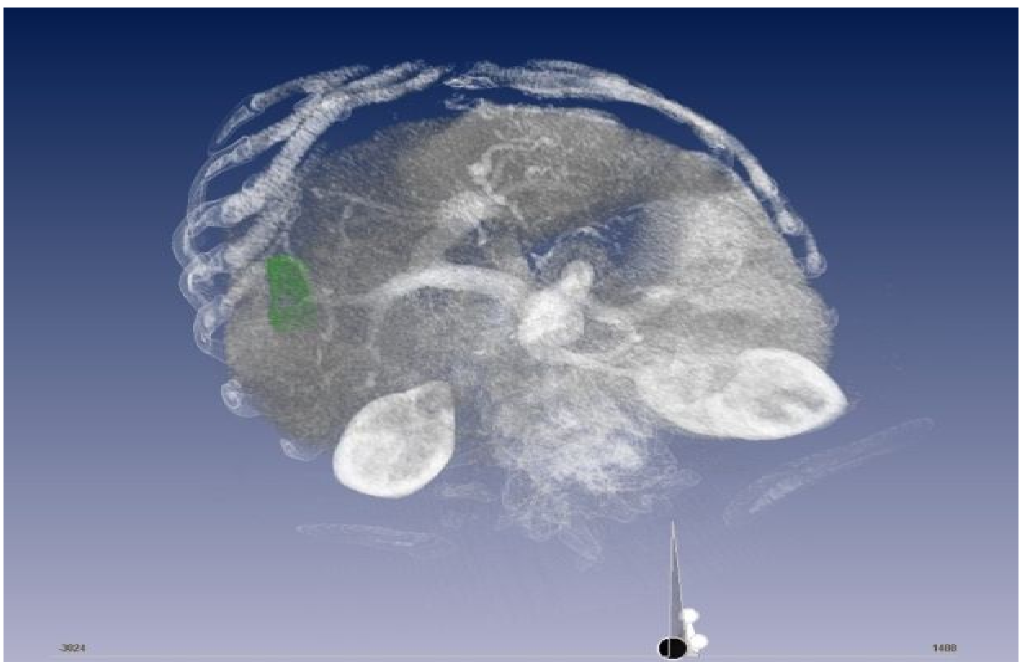

Fig. 3: Focal Liver Lesion – Green [5]

Patient's Position Registration Relative to Pre-Operation Anatomical Liver's Model

As registration process we understand in this case adjustment of points on the patient's body relative to points on preoperation anatomical model. Registration process takes place using markers placed on abdominal cavity surface before computer tomography is performed. Markers placement is presented in table 1 and figure 4. To perform registration, placement of markers is found on computer tomography images and on patient's body surface. Having a set of markers' coordinates in both coordinate systems Horn algorithm is used [3] in order to find stiff match between coordinate system of personalized anatomical liver's model and coordinate system related to real position of the patient on an operation block. Stiff match between patient position and personalized anatomical model during treatment is not sufficient due to deformations of patient's body taking place due to breathing movements and pressure of surgical tools. To take those things into consideration non-stiff registration is introduced which allows to take into the account local shape deformations.

Table I. Anatomical Position of Skin Markers for Manual Registration

Marker number	Anatomical location	Grounds
1	Xiphoid process	Point fixed to bony structures in the midline of the body
2	Intersection of midclavicular line and right costal margin.	Anatomical point. fixed to bony structures
3	Intersection of anterior axillary line and right costal margin.	Anatomical point. fixed to bony structures
4	Intersection of midclavicular line and left costal margin.	Anatomical point. fixed to bony structures
5	Intersection of anterior axillary line and left costal margin.	Anatomical point. fixed to bony structures
6	First control point on the abdominal surface	Registration accuracy validation

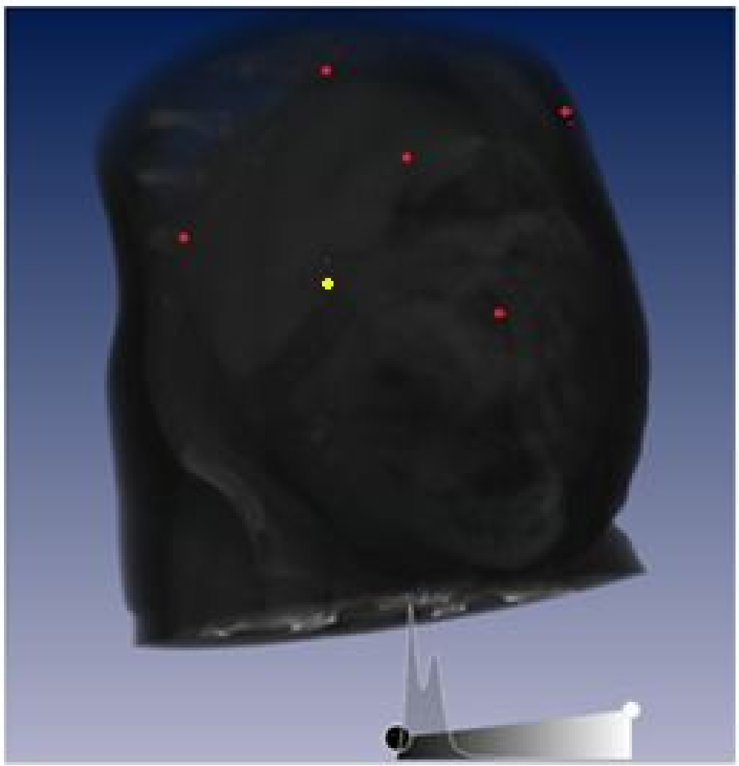

Fig. 4: Abdominal Surface of the Patient with Markers (Markers - Red, Entry Point - Yellow) [5]

Non-stiff registration is based on so called deformation field, which is in turn based on a markers position interchanges, which are observed continuously during treatment. Based on deformation field, correction of target point position is estimated.

Visualization of Operation Field during Treatment

In order to aid treatment performance graphical interface has been proposed which presents current position of surgical tools (in this case ablation needle) on personalized anatomical patient's model. Current position of ablation needle is tracked by position tracking system NDI Polaris Vicra. Key element which is crucial for successful ablation treatment in starting phase is placement of ablation needle ending as close as possible to the proposed target point. For this purpose serves viewer interface, which shows ending of ablation needle position relative to target point during needle introduction, and deviation of needle introduction direction relative to direction between entry and target points which are found during treatment planning phase [7]. Second important element is to monitor tumour's ablation process. In order to do it bipolar system of electrical ablation with radio frequencies Celon produced by Olympus has been integrated. It allows for non-direct ablation process monitoring through tracking of electrical parameters: tissue resistance, momentary power and total energy delivered to the apparatus.

Results

Studies were verified on anonymized cases of abdominal cavity computer tomography. Due to lack of ability to verify segmentation results directly in the case of vascular tree as a measure of segmentation results level of vascular structure branches has been proposed. Vascular tree segmentation has been performed successfully to third or fourth level of branches on average (see figure)[9]. In the proposed methodology automatically obtained segmentation results are submitted for verification by radiologist and only then verified model serves in the next phase of planning of destroying focal lesions. Registration algorithms verification has been performed using abdominal cavity phantom. In order to evaluate quality of registration results measures proposed by [4] has been used: Fiducial Registration Error (FRE), Fiducial Localization Error (FLE) and Target Registration Error (TRE). Despite the fact that those errors are correlated, clinically the most important one is TRE defined as target registration error, that is difference between registered and real position of target during treatment. In the presented methodology Horn algorithm has been studied for stiff and affine transformation and TRE has been respectively 1.75 mm and 0.8 mm. Correctness of proposed method of deformation field calculation has been verified on volunteers, using markers on abdominal cavity surface and assuming that one marker is the target. Tracking other markers and indicating, based on their position interchange, estimation of target marker's movement correction due to breathing movements, average error median has been obtained TRE 2.97 mm for exhale and 7.21 mm for the whole breath. Smaller errors for exhale are caused by the fact that computer tomography screenings were performed during this breathing phase. Correctness of field visualization algorithms in real time during treatment was also verified.

Conclusions

Conducted pilot studies confirmed possibility of application of proposed methodology for destroying focal liver lesions. Further studies direction is to fully integrate proposed methodology in the clinical environment and to verify correlation between external markers movement with internal organs displacement.

Literature

Phee S., Yang K.: Interventional navigation systems for treatment of unresectable liver tumor Medical and Biological Engineering and Computing, 48 (2), pp. 103-111. 2010

Peters T., Cleary K.: Image-Guided Interventions: Technology and Applications Springer 2008

Horn B., Hilden H., and Negahdaripour S.: Closed form solution of absolute orientation using orthonormal matrices. J Opt Soc Am A 5(7),1127-1135, 1988

Fitzpatrick JM, West JB, and Mauer CR, Jr.: Predicting error in rigid-body point-based registration. IEEE Trans Med Imaging, 17(5), 694-702, 1988

Spinczyk D. System nawigacji obrazowej w ablacji zmian ogniskowych w wątrobie. Wydział Inżynierii Biomedycznej. Politechnika Śląska 2013.

Spinczyk D., Karwan A., Rudnicki J., et al. Stereoscopic liver surface reconstruction. Videosurgery and Other Miniinvasive Techniques 2012; 7 (3): 181-187

Seitel A., Maier-Hein L., Schawo S., Radeleff B., Mueller, S., Pianka F., Schmied B., Meinzer H.: In-vitro evaluation of different visualization approaches for computer assisted targeting in soft tissue Computer-Assisted Radiology and Surgery 2 (1 SUPPL.) , pp. S188-S190 2007

Pereira P.: Actual role of radiofrequency ablation of liver metastases Eur Radiol (2007)

Rudzki M.: Filtr wieloskalowy w detekcji struktur naczyniowych wątroby z obrazów tomografii komputerowej. Rozprawa doktorska. Politechnika Śląska w Gliwicach, 2011

Juszczyk J.: Sekwencyjna segmentacja wybranych struktur anatomicznych w serii obrazów tomograficznych. Rozprawa doktorska. Politechnika Śląska 2012

Badura P., Piętka E.: 3D Fuzzy Liver Tumor Segmentation, Information Technologies in Biomedicine, Lecture Notes in Computer Science, 2012, vol. 7339, p. 47-57, Springer Berlin/Heidelberg, DOI: 10.1007/978-3-642-31196-3_5