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Facial Feature Removal for Anonymization of Neurological Image Data

Abstract: Interdisciplinary exchange of medical datasets between clinicians and engineers is essential for clinical research. Due to the Data Protection Act, which preserves the rights of patients, full anonymization is necessary before any exchange can take place. Due to the continuous improvement of image quality of tomographic datasets, anonymization of patient-specific information is not sufficient. In this work, we present a prototype that allows to reliably obscure the facial features of patient data, thus enabling anonymization of neurological datasets in image space.

Keywords: Anonymization, Facial Feature Removal.

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1 Introduction

Digital imaging and communication in medicine (DICOM) was developed to standardize medical image data and to exchange it easily between computer systems. The majority of medical imaging uses the DICOM file format not only for clinical practice but also for clinical research [1]. This leads to the possibility of sharing or exchanging data. However, the proper removal of Protected Health Information (PHI) is of paramount importance to ensure data security and patient privacy. For example, attributes such as the patient's name, gender and date of birth are only available in the DICOM data in pseudonymized form.

However, identifying the patient by their face is an ongoing problem. Especially since the spatial resolution of various image modalities such as magnetic resonance imaging (MRI) and computer tomography (CT) is steadily increasing. Three-dimensional volumes can be rendered relatively easily from these DICOM data sets. Therefore, researchers at the US Mayo Clinic trained an artificial intelligence for facial recognition in 2019. This software was able to recognize a person's face by means of an MRI scan and match it to the corresponding photo in 83% of the cases [2]. To overcome this problem and thus ensure anonymization, the removal of facial features is necessary.

Eyes, nose and mouth are especially significant when identifying a person [3]. However, as recognition technology improves, ears also provide a way to identify a person [4]. Defacing these features may be a more appropriate approach because the rest of the scan will remain intact [5].

In the present study, we developed an automated application for removing identifiable facial features from the volume. We investigated how robust the tool is to image datasets that differ in image modality, image cropping, and image orientation.

2 Materials and Methods

In this section, we describe the medical image data and our developed prototype.

2.1 Medical Image Data

In order to cover different variations of medical image data which is acquired in daily clinical practice in a Neuroradiologic Department, we gathered 16 different image data sets in close collaboration with the University Hospital of Magdeburg. The datasets are listed in Table 1.

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Table 1: Image datasets with their specific properties.

Image Set	Image Modality	Series Description	Image Details
Pat4_1	MR	T1_SE	Tip of the nose to the vertex.
Pat4_2	MR	T2_TSE	Tip of the nose to the vertex.
Pat7_1	MR	T1_SE	Spina nasalis anterior to vertex.
Pat7_2	MR	T2_TSE	Spina nasalis anterior to vertex.
Pat9_1	MR	T1_3D	Tip of the nose to the vertex.
Pat9_2	MR	T2_TSE	Tip of the nose to the vertex.
Pat14_1	MR	T1_SE	Tip of the nose to the vertex.
Pat14_2	MR	T2_TSE	Tip of the nose to the vertex.
Pat15_1	MR	T1_3D	Chin to vertex
Pat15_2	MR	T2_TSE	Chin to vertex
Pat16	MR	Black Blood	Chin to vertex
Pat22_1	MR	T1_3D	Chin to vertex
Pat22_2	MR	T2_TSE	Chin to vertex
Pat23	MR	Black Blood	Chin to vertex
Pat24	CT	CoW to Arch 100ML	Neck to vertex.
Pat25	MR	-	Nose to forehead.

2.2 Developed Software Prototype

The semi-automatic software prototype for facial feature removal was developed with Matlab's (MATLAB 2021a, MathWorks, Natic, U. S.) "App designer" functionality in order to provide a graphical user interface. The graphical user interface was designed with clarity in mind, see Figure 1. In addition, the application and its functions should be as self-explanatory as possible. At the same time, the workflow is conceivably simple. The first step to a defaced dataset is to open a 3D DICOM file. It does not matter whether it is a 3D MR or CT scan. Similarly, image orientation and use of contrast agent or sequence weighting are not important. The image section can extend from the chest to the head or contain only a small section of the face.

After selecting a data set, it is rendered directly and displayed as a volume. Now the user has the choice which elements should be anonymized. This depends entirely on what information the data contains. For example, if there is only a section of the face from the nose to the crown of the head, it is not necessary to remove the chin. Furthermore, the degree of severity of the defacing must be adjusted. This means that the user selects how deep the layer of the face should be defaced in mm.

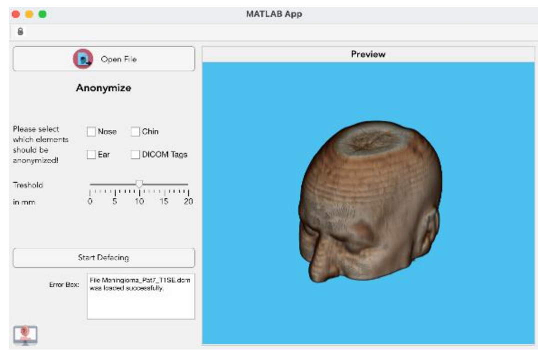

Figure 1: Graphical user interface of the defacing prototype.

Clicking on "Start Defacing" initializes the anonymization. Each completed work process is displayed as a message in the "Error Box". If the volume was successfully defaced, the result is visualized in the preview panel. All work steps are reversible. When a satisfactory result is achieved, a new defaced DICOM file can be saved.

2.2.1 Technical functionality

The operation is divided into three major sections. Prior anonymization, pre-processing takes place to eliminate possible artifacts. These artifacts are illusory phenomena without an anatomical correlate. Surrounding air, which is almost not absorbed by X-rays and therefore has a CT number of -1000 HU, must also be removed. A threshold was used to remove the air, setting all voxels with an intensity less than -900 HU to a value of 0. Connected component analysis was used to remove image artifacts.

Once the artifacts are reliably removed, the algorithm starts registering prominent landmarks on the volume. These landmarks serve as orientation for the Defacing algorithm.

Prominent landmarks include the tip of the nose, nasion (center of the suture between the nasal bone and the frontal bone), the glabella (also over-eye bulge) and the voxel that lies outermost between the tip of the nose and the glabella when viewed anteriorly is marked, as well as the point that lies lowest along the volume when viewed laterally (see Fig. 2). Based on these landmarks, the selected elements can be removed. Other facial details such as the cheeks, chin and eye area are always defaced. The threshold value in mm selected by the user plays an important role here. This process describes the final step, which is explained in more detail below.

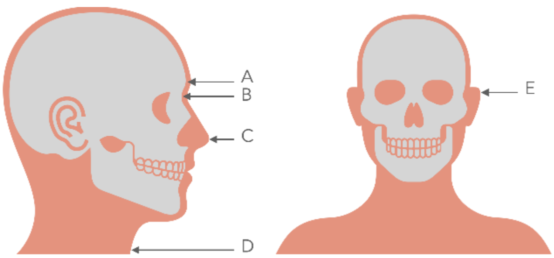

Figure 2: Anatomical landmark A to E. A- Glabella, B- Nasion, C-Tip of nose, D- Neck and E- outer ear.

2.2.2 Distance based Feature Removal

With our distance-based feature removal, the threshold value is decisive for the degree of defacement. Thresholds from 0 to 20 mm are available regardless of the volume rendered. The value determines the amount of altered voxels with an intensity greater than 0. This only affects the voxels that are ventrally oriented. Only features that lie on the front of the body and between landmarks A and D will be defaced. Choosing the minimum threshold will not disfigure any facial features, a maximum of 20 mm results in severe disfigurement. For all available DICOM test datasets, this range has resulted in complete disfigurement of identifiable facial features. On average, a threshold of 10 mm has been found to be sufficient. At any time, the threshold can be changed without reloading the dataset. Whereby a loss of brain tissue can be excluded, due to the limitation by the landmarks.

2.2.3 Removal of Facial Features of the Nose Region

To deface the nose, the depth of the nose and the width must be determined. For this purpose, the landmarks C and B are considered. The distance between both markers is calculated and serves as a measure for the depth of the cut. However, the width is determined by the total width of the volume. This means that for a sagittal scan, the number of slices determines the width of the nose section. This ensures that the entire nose is removed, but at the same time no critical structures are damaged.

2.2.4 Removal of Facial Features of the Chin Region

The chin also depends on two landmarks. Along the entire width of the volume, a straight line is calculated between landmark C and D. This straight line then serves as the section plane. All voxels leading ventrally away from this plane are assigned an intensity of 0. Thus, cutting off the chin is only possible if the dataset also includes information of the neck. Otherwise, as described in Section 2.1.2, the chin is defaced with the threshold set.

2.2.5 Removal of Facial Features Comprising the Ear Regions

Probably the most critical part of disfiguring facial features is the removal of the ears. Since there is not much buffer zone to relevant brain structures. Three landmarks are needed for this process. Landmark E marks where the outermost voxel is located on the skull when viewed laterally. This is the starting point for the removal. Landmark C and A mark the lower and the upper boundary for the cut, respectively. The cutting depth is calculated as a percentage and is therefore based on the dimension of the volume. The width is also calculated as a percentage but offers enough space to include larger ears.

3 Results

We applied our prototype successfully to all datasets listed in Figure 3. For visualization of the results, a uniform threshold of 10 mm was chosen.

Currently, the challenge is to ensure that the rendered volume is as free of artifacts as possible. Image distortions in the vicinity of the ears are particularly problematic. These can prevent the algorithm from correctly placing the landmark E on the patient's skull. Thus, in case of doubt, only part of the ear is removed or nothing at all. The processing time of the defacing algorithm including volume rendering and elimination of artifacts was 13.724 seconds on average. Pat16 required the maximum runtime of 27.591 seconds with a dimension of 640 x 640 x 427. The voxel size was 0.3906 x 0.3906 mm. At 7.112 seconds, the defacing process for Pat7_2 was completed the fastest. Here the voxel size was 0.5000 x 0.500 mm. The dimension of 460 x 460 x 144 was the smallest among all image datasets tested. The tests were run on a MacBook Pro (early 2015, macOS Big Sur) with 2.7 GHz dual-core Intel Core i5, 8 GB 1867 MHz DDR3 and an Intel Iris Graphics 6100 with 1536 MB.

Figure 3: Three representatives for the test data sets used. The first row shows Pat7_2, the second row shows Pat15_1 and the last row shows Pat24. The left column shows the original data, where the elimination of image artifacts has already taken place. The right column visualizes the defaced results.

4 Discussion

The exchange of data for research projects between different locations is constantly increasing. When processing the data, sufficient security of personal data must be ensured. Nevertheless, not every physician has extensive knowledge in the field of image processing, which is necessary to comply with the guidelines (HIPAA; DS-GVO). The presented tool meets these guidelines in the context of the conducted study and offers a user-friendly interface. Extracranial CSF and brain tissue is not removed in the process. Only the removal of the ears still shows some weaknesses when many image distortions are present. Comparison with related work shows that the strengths of the tool lie in its versatility. Publicly available algorithms such as mri_defacer use the skull stripper method for disfigurement [5]. This is suitable for 3D T1-weighted sequences. Also, DeepDefacer is specifically designed for defacing 3D MRI images [6]. The algorithm used here proofed to be a reliable method for defacement for all datasets tested. Some datasets, especially the T2-weighted MR scans, were of poor quality. Neither image modality, image detail, nor diagnosis played a role in the defacement process. Human intervention cannot be completely ruled out. However, this allows the user to retain control over how much detail is removed. One step towards automation is to define default values for anonymization. These would then only be adjusted at the user's discretion.

Overall, we found that the defacing algorithm effectively removes facial features and ensures sufficient defacing of the ears. Whereby no brain tissue is sacrificed. Moreover, the tool is easy to use and does not require advanced computer science knowledge.

5 Conclusion

We provide a software tool for removal of facial features thus enabling anonymization of neurological datasets in image space complying with the guidelines of security of personal patient data. At the following link the prototype for removing facial features can be downloaded for free: https://gitlab.stimulate.ovgu.de/sylvia/deface.

Author Statement

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