FACE-R – 3D skull and face database for virtual anthropology research

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Abstract – The “FACE-R” database can be used as an updated chart for the more detailed morphometric analysis of the possible factors affecting facial features. The database in this phase will use a MYSQL engine. This engine is chosen as it handles sophisticated data types, for its object oriented capabilities, available programming language interfaces, wide range of extensions – possibly helpful in parsing 3D surface data. The public web-based interface offers access to 400 living individuals’ face and skull 3D data. It will also offer restricted access to the database – the restrictions are due to bandwidth and personal right issues. With 4 figures.

Key words – 3D imaging, CT, database, face scan, forensic craniofacial reconstruction, morphometry

INTRODUCTION

Craniofacial reconstruction is the modelling of the face based on the shape and surface structure of the mimic muscles and the skull bones (GERASIMOV 1971). Approaching the outlines of the face is achieved by applying a soft-tissue layer onto the skull according to average measurement data.

Nowadays, there are numerous publications on soft-tissue variability (STEPHAN & SIMPSON 2008). The use of soft-tissue data for a specific reconstruction takes into account the race, gender and physique. The data collection of the last few decades, however, has relied on up-to-date technologies, such as ultra-sound (LEBEDINSKAYA et al. 1979, WILKINSON 2002, CLAES et al. 2006, DE GREEF et al. 2006) and X-ray equipment. These newer approaches are more accurate on living subjects, but still suffer from other disadvantages, which are
that data are only collected for a limited number of feature points and on a limited sample. Though CT and MRI technologies produce 3D images of the skull and the face (Berar et al. 2006, Vandermuehen et al. 2006, Tilotta et al. 2009, Rynn et al. 2010, Guyomarc et al. 2010), due to participants being usually in supine position during the scan, the gravity can affect the face (See et al. 2008).

Formerly the use of facial reconstruction was mostly restricted to gaining information relevant to (pre)historic anthropology, while today there is an ever growing need not only in anthropology, but also in forensics and in medicine (e.g. for prosthetics and plastic surgery). There are also a number of software applications – mainly for legal or police services – that can help reconstruct the soft parts of the face (Vandermuehen et al. 2006, Claes et al. 2006).

Even though computer-assisted processes allow for a much quicker and flexible facial reconstruction than the traditional facial reconstruction methods (Wilkinson 2005), the lack of some basic research and the limited number of available databases yield, in our view, rather inadequate results. One issue with the widespread methods of computerised craniofacial reconstruction is that the included guidelines are based on scientifically only partly controlled, subjective observations. Such uncertainties result in the inaccuracy of the approach, thus the efficacy of craniofacial reconstruction is also questionable (Stephan 2003a). While many papers were published on soft tissue data, there are only a few on the skull and face-shape relations (Stephan 2002, 2003b, Rynn & Wilkinson 2006, Rynn et al. 2010, Guyomarc et al. 2010).

Therefore, an improved understanding of craniofacial hard- and facial soft-tissue morphology is crucial, as well as the degree to which the two co-vary, which requires the statistical analysis of large data sets.

MATERIAL AND METHODS

In order to perform the statistical analysis of large data sets we established a 3D face and skull database of living individuals, the FACE-R research database.

We chose a sample enabling the observation of the face and skull of the same person. The most suitable process for this was to rely on clinical patients who were sent to the Radiology Clinic for head CT diagnostics. We opted for this approach in order to avoid exposing healthy individuals to x-rays only for the purposes of this study. Close co-operation with the volunteer patients, and having the necessary permits, enabled the implementation of data collection of 400 individuals.

CT scan data – CT records of the whole head were obtained at Semmelweis University, Department of Diagnostic Radiology and Oncotherapy (Budapest) with a multislice spiral CT scanner (Philips Brilliance CT 16 slice, Software
We used a special protocol with a pitch of 1.0, an increment of 1.0 mm. This generally resulted in ca. 560 CT records for the whole head.

3D surface scan data – Because the CT records were made with patients positioned on their back, the soft-tissue geometry is altered under the effects of gravity. For this reason, the CT-based skin surface data are not reliable for the geometric analysis of the face. A novelty of our database and approach is that we were able to solve this issue by applying additionally 3D surface scanning to the face, while the subject is in a natural, seated position.

We used the special Breuckmann FaceScan-III-180 for 3D scanning the face of the volunteers. Since we utilised static adjustments, the light settings (except for the values of brightness and gain) and the OPTOCAT 2009 software (Version 8.00.17 – 1503) parameters remained the same throughout data acquisition.

3D-aligned “Face oriented to skull” models – The surface of the bone and the skin was reproduced in 3D using RAPIDFORM2006 SP2® and Geomagic Studio® 10 software. We created accurate 3D-aligned models from the bone surface of the CT and the skin surface of the face scan record based on soft-tissue portions not affected by gravity (Figs 1–3). This ensures the comparison of the two tissues of the same individual in the same anatomical reference system. Several technical tests were carried out before creating the final 3D models for the morphometric analysis (KUSTÁR et al. 2013). This also included a test of the accuracy of the two imaging techniques, which was done by using a plaster model of a head.

RESULTS

Database – The “FACE-R” database in its present form serves archiving and documenting and query purposes for the processing of data. The archiving scripted in Perl and queries are PHP/SQL scripts (CELKO 2002, DUBOIS et al. 2005, TOMLINSON & VANDYK 2010). The database consists of two parts:

A folder structure stores the files of the processing step from raw CT and scanned data to the finally normalised 3D object files. The folder and file naming contain enough information to identify the file content. The filenames are composed of the unique StudyID and the type of data, further information on software and software setting is also indicated. This form of storage is self-descriptive and offers great portability because the data retrieval is not database engine dependent – only simple zipped archives are managed. The GNU/Linux server offers the usual wide range of tools for managing and parsing files, the users can access the files via encrypted ftp clients (sftp) using their own private keys.

A relational MYSQLite database duplicates the file information, stores administrative information and biological information of the patients (e.g. ances-
Figs 1–3. Steps of the alignment of CT- and Face-scan data: 1 = using thresholding to segment soft- and hard-tissues in CT-scan data, 2 = superimposing the face-scan onto CT, 3 = final alignment of face-scan onto CT skull data

Fig 4. Query structure of the FACE-R database
try, age, sex, body height, body weight, BMI, developmental anomaly, trauma, relevant medical treatment, braces, dental prosthesis, or anything else, etc.).

The MYSQL database stores the original data files as well as the additional information gained during processing.

Public interface – A special extract of the FACE-R database has been transferred to the public web based portal’s proper MYSQL database.

The database display occurs via DRUPAL 7.xx 7.22 front (Schwartz et al. 2012).

The public database contains the following types of query data:

- **StudyID**: Identity number of the records.
- **Biological data**: Sex.
- **Biological data**: Age/Year.
- **Original (raw) data projects**: CT_project.
- **Original (raw) data projects**: SCAN_project.
- **Processed 3D data**: CT_3D (skull).
- **Processed 3D data**: SCAN_3D (face).
- **Processed 3D data**: Face oriented to skull (the aligned skull- and the face in the same file).
- **Skull 3D Images**: Quick view of the skull in pdf. (Opening the 3D Image pdf requires running Adobe Acrobat Reader).
- **Comments**: Serves with information about completeness or incompleteness the row of data.

Users can query the required information for each column in the drop-down menu on the top of the page, and one can select – any, ready or missing – data (see Fig. 4).

**Data protection** – The FACE-R database is operated by the Hungarian Natural History Museum, Department of Anthropology. We kept the personal data of patients private, respecting the data protection regulation. The far access to the server requires the SSH keys. Only the database administrators possess the direct SSH access to the server. Upload and download is feasible applying to SFTP.

**Data security** – The data are stored on a Linux server. The integrity of data is protected by store in RAID-1 system that is complemented with USB disc rescue. The external data rescue turns on in when data is surveyed and modified.

**Access** – FACE-R database is available at the website of Hungarian Natural History Museum (http://193.224.72.252:26985/). In order to contact us, the external users should join to the home page than choose “Search in database” menu item and click on “Contact us”. The access conditions were shaped by the Research Regulation of Hungarian Natural History Museum.
*Acknowledgements* – The study was made possible by the support of the Hungarian Scientific Research Fund (OTKA No. K73441). We would like to take the opportunity to thank Breuckmann (http://www.breuckmann.com) for the Facescan loan. Finally yet importantly, we express our gratefulness to the volunteers for giving their data for our disposal and the radiology assistants for their extra work.

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