First visualization results of intraoperative multispectral tissue differentiation

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Purpose: Multispectral imaging as a contact-free and fast imaging method allows to acquire the remission spectra in the visual and near-IR spectral range as well as the spectral reflectance curve of biological tissue. These spectra contain richer information about the tissue types and the structural features than normal three channel RGB-imaging techniques, allowing to differentiate between neighboring tissue types that are visually similar to the human eye. We have built up multispectral imaging systems to analyze and differentiate the relevant spectral tissue characteristics not visible to human eyes in order to support the surgeon's tissue differentiation process. For example, the nerve preparation is the most challenging and time-consuming task during parotidectomy and an improved nerve visualization would help the surgeon to accelerate the surgical process and lower the risk of nerve injuries. In this work, we present a first approach to visualize multispectral tissue information without losing relevant RGB-information in the images.

Methods: We built the proposed visualization approach upon our previously presented imaging setup including two multispectral snapshot camera featuring a 4x4 (16-band) mosaic (visual range) and a 5x5 (25-band) mosaic pattern (visual and near-IR range) as recording devices [1]. Using this setup, we are able to reconstruct the remission spectra of each captured pixel, i.e. of the different tissue types in the situs. A regular RGB image can be calculated from the 16 + 25 scanned wavelength bands with the CIE color matching functions. Such calculated RGB image holds no additional spectral information. In order to visualize additional relevant tissue information in the image, we propose the following basic concept for partial color enhancement without destroying the color balance. This color enhancement is applied to the high dimensional multispectral image and uses statistical orthogonal transformation

The enhanced multispectral data f_e is calculated by

$$f_e(u,v) = \boldsymbol{W}[f(u,v) - s(u,v)], \tag{1}$$

with

$$f(u,v) = \sum_{i=1}^{N} \alpha_i(u,v) e_i + \bar{f},$$
$$s(u,v) = \sum_{i=1}^{m} \alpha_i(u,v) e_i + \bar{f},$$

where u and v represent the pixel positions, e_i is the i^{th} basis vector of the transformation of the measured multispectral image f and α_i are the corresponding statistical transformation components, $\bar{f}$ is the average vector of f and s are the parts of the multispectral data retaining as much of the variance in the dataset as possible. The weighting matrix $\boldsymbol{W}$ holds the magnification factor m for color enhancement. The magnification factor m is placed into $\boldsymbol{W}$ at the position of the wavelength bands that are meant to be amplified.

To identify the best wavelength bands for magnification, e.g. for visual nerve enhancement during parotidectomy, we use spectrophotometer measurements of tissue samples of the major present soft tissue types in order to analyze spectral differences between the single tissue types, e.g. for parotidectomy the tissue types nerve, parotid gland and fibrous connective tissue, and select appropriate spectral bands [2].

This a-priori knowledge allows to highlight the tissue of interest (e.g. nerve) in the captured image. To preserve the overall RGB-color balance of the reconstructed RGB image, the enhanced image information is added to only one channel of the calculated RGB image.

Results: We investigated different tissue types present in parotidectomy. The most prominent tissue is parotid gland, while nerve (tissue of risk) is the most interesting tissue type besides the tumor and has to be preserved. Figure 1 depicts an example for nerve visualization. On the left side the RGB-image reconstructed from the calibrated multispectral dataset is shown. This image of the situs corresponds to a typical RGB image. The right side shows the same view with enhanced nerve visualization. In this case, the spectral bands, corresponding to higher reflectance intensity for nerve tissue compared to the reflectance intensities of the other surrounding tissues, are intensified by adding this color enhancement data to the blue channel of the reconstructed RGB image.

Thus, the overall color impression in the RGB image is preserved and only a selected tissue type receives an adapted color appearance, in this specific case: the nerve is colored bluish.

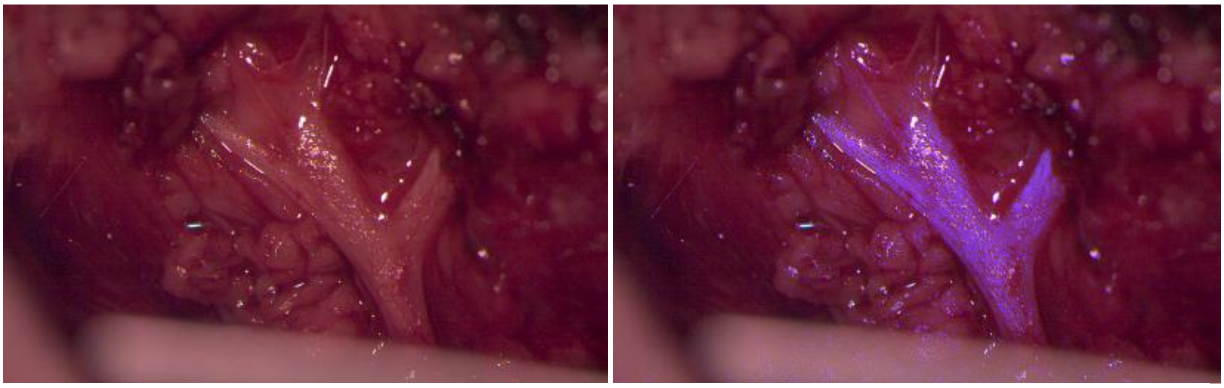

Figure 1: Proposed visualization for tissue differentiation by color enhancement. In the left view a classical RGB-image is calculated from the multispectral data using the CIE color matching function. In the right view the spectral information, specific to the nerve are enhanced and included in the blue channel.

Conclusion: In this work, we present first visualization options to fuse additional multispectral information into the image without concealing relevant anatomical structures and features. In addition, the overall image and color impression is preserved, which allows the surgeon to intuitively understand the visualized added value. These first visualizations show very promising results to bring multispectral tissue analysis systems (using snapshot cameras) into the operation room to open new opportunities for intraoperative assistance and image-guided interventions.

References

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