Prošireni sažetak / Extended abstract

Obrada i modeliranje 3D slike iz ehokardiograma

3D echocardiographic image processing and modelling

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3D ehokardiografija je relativno mlada način ultrazvučnog snimanja koji je razvijen početkom 80-ih godina kada je prvi puta zabilježena off-line trodimenzionalna rekonstrukcija slika iz serije 2D skeniranja više ravnina.[1] U posljednjih deset godina, na ovom području, postignut je impresivan napredak razvojem tehnologije matrične sonde punog polja s oko 3.000 piezoelektričnih elemenata, koja se temelji na naprednoj digitalnoj obradi i poboljšanim algoritmima formiranja slike sposobnim da pruže veću prostornu i vremensku rezoluciju kod ultrazvučnog skeniranja u realnom vremenu. Najnovija dostignuća uključuju trenutnu dostupnost punog matričnog niza u vrhu transezofagusne sonde[2] te najnoviju mogućnost momentalnog snimanja punog opsega kako bi se obuhvatila cijela šupljina lijeve klijetke tijekom jednog otkucaja[3].

Usporedo s tim tehnološkim poboljšanjima, na prikupljene 3D grupe podataka primjenjuje se nekoliko tehnika obrade slike da bi se iskoristile njihove kliničke informacije. Kao rezultat toga, u današnje vrijeme je moguće izračunati dimenzije lijevog ventrikula, ejekcijske frakcije[4] i mase[5] neposredno u 3D tehnici, bez potrebe za primjenom matematičkih formula na kombinirane 2D apikalne prikaze te tako dobiti preciznije i pouzdanije informacije o kardiološkom statusu bolesnika. Također, ovaj pristup je proširen na kvantifikaciju desnog ventrikula[6], kao i na lijevi atrij.

Dostupnost transezofagusnog snimanja je proširila kliničku primjenu 3D ehokardiografije na praćenje kirurških zahvata u realnom vremenu. U tom kontekstu moguće je dobiti izvanredne snimke mitralnog i aortnog valvularnog aparata koje su slične kirurškom prikazu. Ovakve snimke je također moguće obraditi da bi dobili geometrijske informacije o mitralnom valvularnom (MV) aparatu[7], da bi pratili njegove dinamičke deformacije[8], ili kombinirali skupljene kvantitativne podatke da bi dobili stvarni model metode konačnih elemenata specifičan za pacijenta u cilju planiranja kirurškog zahvata. U stvari, prethodna ograničenja vezana uz pristup modeliranja, uključujući pojednostavljenju geometriju listića, planarnih i akinetičkih anulusa i papilarnih mišića sada se mogu prevladati analizom 3D ehokardiografskih podataka i izvlačenjem iz njih informacija potrebnih za prilagodbu generičkog modela morfologiji pacijenta[9].

Kada se koristi za stimulaciju sistoličke funkcije MV s organskim prolapsom, predložena strategija modeliranja pokazuje sposobnost imitiranja s dobrom aproksimacijom stvarnog zatvaranja zaliska, shvatanjem glavnih značajki patologije i

3D echocardiography is a relatively young imaging submodality of ultrasound imaging that was developed in the early 1980s, when off-line three-dimensional reconstruction from serial multiplane 2D acquisitions was reported for the first time[1]. In the last ten years, impressive progresses have been reached in this field by the development of a full matrix array probe technology of about 3,000 piezoelectric elements, based on advanced digital processing and improved image formation algorithms, capable of providing higher spatial and temporal resolution for real-time volumetric acquisition. Further and latest advances include the current availability of a full matrix array into the tip of the transesophageal probe[2], and the recent availability of instantaneous full volume imaging to include the entire left ventricular cavity in a single beat[3].

In parallel with these technological improvements, several image processing techniques have been applied to the acquired 3D datasets in order to exploit their clinical information. As a result, it is possible nowadays to compute the left ventricular dimensions, ejection fraction[4] and mass[5] directly in 3D, without the need of applying mathematical formulas to combined 2D apical views, thus obtaining more precise and reliable information on the patient cardiac status. Also, this approach has been extended to the quantification of the right ventricle[6], as well as of the left atrium.

The availability of transesophageal images has extended the clinical applicability of 3D echocardiography to the real-time monitoring of surgical intervention. In this context, it is possible to obtain astonishing images of the mitral and aortic valvular complex, similar to the surgeon's view. These images can also be processed in order to provide geometrical information of the mitral valvular (MV) apparatus[7], to track its dynamic deformation[8], or to combine these quantitative data together to obtain a realistic patient-specific finite element model for surgical planning purpose. In fact, previous limitations relevant to the modelling approach, including simplified leaflet geometry, planar and akinetic annulus and papillary muscles, can now be overcome by analyzing the 3D echocardiographic data and extracting from it the information needed to adapt a generic model to the patient's morphology[9].

When used to simulate the systolic function of MVs with organic prolapse, the proposed modelling strategy proved capable of mimicking with good approximation the real valve closure, capturing the main features of the pathology, and

omogućavanjem razlikovanja između fizioloških i patoloških uzoraka biomehaničkih varijabli nad podstrukturama MV. Ovaj pristup može omogućiti predviđanje hipotetskih post-operativnih scenarija, kao pomoćni alat za planiranje operativnih zahvata.

Ključne riječi: ehokardiografija, obrada snimaka, modeliranje metodom konačnih elemenata.

allowing discriminating between physiological and pathological patterns of biomechanical variables over the MV substructures. This approach could allow the prediction of hypothetical post-operative scenarios, as a support tool for the surgical planning.

Keywords: echocardiography, image processing, finite element modelling.

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