MOTION DETECTION APPLIED TO MICROTECTONICS MODELLING

M. A. J. Guerra\(^1\) and Vania V. Estrela\(^2\)

\(^1\)MAJOCEAN, Rio de Janeiro, RJ, Brasil, CEP 21003-112
\(^2\)Department of Telecommunications, Universidade Federal Fluminense, Duque de Caxias, RJ, Brazil, CEP 25086-132

ABSTRACT

The foremost by-product of this paper is the automation of geological undertakings, for instance, dealing with exceptionally thin sections of rocks that were subjected to deformation alongside finite steps of time which can be recorded in video for later analysis using image processing and numerical analysis procedures. Markers are used in order to trace gradients of deformation over a sample and study other mechanical properties. Image processing and video sequence analysis can be a very powerful investigation tool and this paper shows preliminary results from its use on microtectonics. The proposed algorithm is a combination of two well-known approaches: feature extraction and block matching.

KEYWORDS

Motion Detection, Grain Deformation, Deformation Models, Image Analysis, Template Matching.

1.INTRODUCTION

Tectonics is the study of significant features in planetary lithospheres that produced deformation. So, tectonics is concerned with the nature and origin of features that would be noticeable in a single glimpse at local geologic maps, plots of the physical appearance of the earth, or images of planets and moons as, for example, marine basins and continents, regionally created faults, fractures systems, mountain ranges, topographically controlled shields, and volcanic arcs. Countless tectonic features on earth are right away evident because they contribute to the physical appearance of the environment. Studies in tectonics seek not only to characterize large-scale features, but also to investigate the deformation forces and displacements responsible for them. Tectonic research is intrinsically multi-disciplinary and integrative, and, like the Greek tecton (builder), it uses numerous tools. To study the growth and decay of mountainous topography, the forces and displacements at relevant plate boundaries can be investigated. Other important phenomena are: (a) the influence of climate on fluvial erosion; and (b) the influence of orogenic topography on local precipitation and global climate. Tectonics covers geological time as a whole, from the early history of the globe and solar system to the immediate present. In order to explain large-scale features, complement studies of active, current tectonic processes with investigations concentrated on the geologic record of past events are needed.

Despite the long term use of rock as a construction material, probably as old as civilization itself, it was only throughout the last two centuries that the need to understand and measure the forces acting in the rock became urgent. The foundation of tall buildings and long bridges, the excavation of lengthy tunnels and deep mines and the drilling of profound wells can only be

DOI:10.5121/ijcsa.2014.4604
safely carried out with knowledge of how rocks respond to changes due to stress. The progress of civil, mining and petroleum engineering has prompted interest in the measurement of rock stresses. Simultaneously, in geology and geophysics, the need for quantitative estimates of the development of folds and intrusions, the movement of earthquake generating faults etc., accentuated the need for estimates of in situ stress from the deep crust. More interest in deep stress estimates was triggered by the plate tectonic revolution. Plate tectonics has described successfully various tectonic processes, but the forces that drive the plates are still not well understood. The study of mechanical stresses in the lithosphere can help finding (i) which forces act on the plates; (ii) where they act; (iii) their magnitudes; and (iv) to where they are transmitted. The recent interest in stress transfer and stress triggering of earthquakes requires detailed knowledge of crustal stresses, before and after large earthquakes. Accurate estimates of the background stress field and the perturbations caused by smaller groups of events will help understanding earthquake generating mechanisms and, hopefully one day, the forecasting of earthquakes [2, 3, 4, 24].

Microtectonics is the branch of geology concerned with thin sections studies of rocks with the aim of reconstructing tectonic evolution. The observations obtained from the microstructure of a rock can be used to: i) understand metamorphism and mechanisms of rock deformation; or (ii) to reconstruct the structural and metamorphic history (tectonic evolution) of a volume of a rock [3, 4].

The automation of geological tasks is proposed to gain more understanding on the role and effects of anisotropic grain growth study in rocks. This work deals with particularly thin sections of rocks submitted to deformation alongside predetermined steps of time, which can be recorded in video sequences, for later analysis by means of image processing and numerical analysis techniques. Taking a 2D view of the problem, grain boundaries can flow to accomplish a local minimum surface energy configuration.

Finite dislocation paths have to be reconstructed from incremental deformation patterns; if we take two stages of the experiment that are closed together in time, e.g. two subsequent images of the film, these can be used to find to incremental deformation pattern. Finite dislocation paths can be precisely reconstructed by adding on incremental deformation patterns [8].

Figure 1. Thin sample sections of a rock as seen at a given time instant: (a) RGB image; and (b) Scale.
The results from microtectonics analyses can be combined with remote sensing techniques in order to create thematic maps [15, 16, 20]. Section 2 explains the dynamics of grain interaction. A motion detection algorithm is used to establish the correspondences of markers put on the sample slice in Section 3. Experimental results are shown in Section 4. Finally, some conclusions are drawn.

2. GATHERING DATA

The world can only be geometrically described with the selection of reference frames, so that measurements are feasible. Typically, a Cartesian system with 2, 3 or 4 coordinates is used, along with a metric scale. Microtectonics has a tendency to take parts of the whole sample as the reference frame. In a large-scale investigation, however, it may be more constructive to get the autochthonous basement as the reference frame.

Evidently, a sound analysis of microstructures requires accurate sampling and the right picking of the direction from which thin sections are ripped from rock samples. After the due treatment, the image obtained via microscopy shows several grains with different distributions, sizes, shapes, orientations and color intensities (Figure 1). There are sharp transitions in color known as grain boundaries.

What prompts grain boundary movement (anisotropic grain growth) in rocks may be a product of (usually inhomogeneous) deformation, the result of chemical potential gradients, or the inherent grain boundaries surface energy (Figure 2). The dominant deformation mechanisms throughout laboratory experiments can be constrained from constitutive relationships of stress, strain rate, temperature, and grain. The microstructures resulting from such experiments can be examined and correlated to the dominant processes with the help of mathematical/computational modeling. Thus, links between natural and experimental microstructures can provide constraints on dominant deformation mechanisms in tectonic changes. However, problems related to data extrapolation of from investigational to natural situations, and the possibility that more than one mechanism may be operating during the experiment necessitate independent methods of assessing the evolution mechanisms in natural and experimental samples. Furthermore, the balance of processes such as recovery and different re-crystallization mechanisms may modify material behavior without giving rise to an identifiable signal in the constitutive relationships.

The monitoring of deformation gradients over a sample is done by insertion of fine powder (marker particles), i.e. silicon carbide, in the sample. These markers do not react with the thin section of the rock and they are not supposed to disturb the deformation process. The position of
these passive material points at various stages of the experiment can be used to reconstruct local
deformation.

![Figure 3. Sequence of video frames recovered from a deformation experiment.](image)

Figure 3. Sequence of video frames recovered from a deformation experiment.

![Figure 4. Block matching algorithm for motion estimation [30-32].](image)

Figure 4. Block matching algorithm for motion estimation [30-32].
3. MARKER MOTION DETECTION

Feature point tracking is a standard computer vision task with numerous applications in navigation, motion understanding, surveillance, scene monitoring, and video database management. In an image sequence, moving objects (markers) can be detected prior to tracking or during tracking. These points may have local image properties assigned to them. However, in dynamic scenes these properties are often unstable.

To facilitate the obtaining of the best equivalent block in the new frame, it is crucial to compare the present block with all the prospective blocks of the reference frame. Regardless of the type of search algorithm used to determine the best match, at least one metric has to be employed to point out how close adjacent blocks are. Full search motion evaluation calculates the sum of the absolute difference (SAD) value at each potential location in the search area [25]. Assuming that each block has $16 \times 16$ pixels, the SAD is given by

$$SAD(x, y, r, s) = \sum_{i} \sum_{j} |A(x+i, y+j) - B(x+r+i, y+s+j)|,$$

where $i=0, \ldots, 15$; $j=0, \ldots, 15$; $(x,y)$ stands for the position of the current block $A$; and $(r,s)$ corresponds to the displacement or motion vector between $A$ and the reference frame block $B$.

The first approach was to identify which points in the frames were markers, by looking at their neighborhood pattern and, if existed some sort of displacement vector between consecutive frames, in the traditional statement of the feature point tracking problem.

The original video sequence was in color and, at this research stage, no pre-processing was assumed, except for the conversion from RGB to gray scale.

3.1 Problem Statement

Consider a motion sequence of multiple objects viewed by a static camera. Assuming no particular 3D model of motion, the problem is restricted to 2D projection of real 3D motion.

![Figure 5. Three different marker trajectories along a video sequence, where $v_e, v_e', v_s$ and $v_s'$ are motion vectors [2].](image)
Figure 6: First two frames of the microtectonic video sequence “SR5_05de.mpg” after RGB to grayscale transformation.

Figure 7. The white dots shows points with thresholds greater than 120.

Figure 8. Blue dots represent points classified as markers in frame 1 while red ones are “markers” identified in frame two.
The motion estimation via block-matching is the most usual method for motion detection in video. In order to improve the displacement vector computation, 2D/2D block correspondences between consecutive frames (Figure 4) is proposed [10, 11, 13] based on the fact that the markers will appear in a given frame as a small dark spot.

The method of block-matching is illustrated in Figure 4 where each frame is separated into blocks, each of which may have luminance and chrominance blocks [9, 11, 21, 23]. More often than not, motion estimation is done exclusively on the luminance (gray scale) image. Every single one luminance block in the present frame is matched against prospective blocks in a search area on the reference frame. These prospective matching blocks are just the shifted versions of the original block. The best candidate block is located and its displacement or motion vector (MV) is recorded [12, 13, 14, 17, 18, 19, 22].

Algorithm:

For each pair of images throughout the whole video sequence do:

1. Extract borders
2. Remove contours
3. Establish marker correspondences

Fig. 5 shows the expected results from a situation where we have 3 different marker trajectories sampled at 6 different finite time intervals. The arrows correspond to displacement vectors or to velocities depending on the way sampling is done. Usually, flow in a material is heterogeneous, i.e. the flow pattern varies from place to place in the experiment and the result after some time is inhomogeneous deformation. However, if considered at specific scales, flow may be more or less homogenous. The result after some time is homogenous deformation. In Fig. 5, pairs of material points (markers) appear connected by straight lines and these connecting lines help to register the stretching rate and angular velocity of the markers [1, 2, 5, 24].

4. EXPERIMENTS

This work deals with the first two frames of a real video sequence (Fig. 6). The active modification mechanism in a material hinges on the homologous temperature, confining pressure, strain rate, stress, grain size, existence of a pore fluid, occurrence of impurities in the material. These phenomena are not entirely independent, for instance, for a pure material of a predetermined grain size, at a known pressure, temperature and stress, the flow-law associated with the particular mechanisms can be found by means of the strain-rate. Several mechanisms may be working under a known set of conditions and some mechanisms cannot function autonomously, but operate together with an additional one in order that noteworthy permanent strain can develop. In a single deformation occurrence, the prevailing mechanism may vary as a function of time e.g. re-crystallization to a fine grain size at a premature stage may permit diffusive mass transfer processes to turn out to be dominant.

The discovery of the active mechanisms in a material constantly calls for the application of microscopic techniques usually using a combination of optical microscopy, scanning electron microscope (SEM) and transmission electron microscopy (TEM). The images used in this work have been obtained by means of TEM. Sample preparation in TEM can be difficult, since it depends on the material under analysis and the desired specimen data. As such, numerous generic techniques have been employed for the preparation of the necessary thin sections.
In material science, the specimens tend to be naturally resistant to vacuum, but still must be prepared as a thin foil, or etched, so that some portion of the sample is thin enough for the beam to penetrate. There are other constraints on the thickness of the material that deserve attention.

It has been feasible to depict the states under which individual deformation means govern some materials in the form of deformation mechanism maps. This is done after submitting thin slices to a combination of experimental deformations, while filming the results, in order to find the flow-laws in particular conditions and from the microscopic examination of the samples afterwards.

Some possible candidates to be considered as markers are shown in Fig. 7. It is quite difficult to point out the real markers, even by visual inspection. Fig. 8 tries to find correspondences between markers.

4. DISCUSSION AND FUTURE WORKS

The main goal of this paper is to explain how microscopic evidence contributes to know and to understand the processes responsible for the development/evolution of rock formations. A numerical depiction aiming at simulating anisotropic grain growth has been developed, which opens room for additional mathematical and computational modelling of processes related to grain growth.

Very thin slices of rocks had been submitted to deformations whose image observations obtained via a microscope guided the analysis of the grain modifications with the help of markers. This work is concerned with finding the displacement vectors of markers, after some image pre-processing [6, 7], in order to correctly classify the markers. It is also necessary to establish the acceptable magnitude for a marker displacement vector.

The evolution of the markers can be used as an initial analysis stage. Depending on these findings, a more complex investigation can be done by combining both geological and image processing metrics as well as models with the aim to depict the grain boundary deformation of samples with respect to time.

Optical flow algorithms can help when more detailed information about the behavior of borders [7, 11-19]. Deformation models may also aid describing the evolution of grains [26, 27].

ACKNOWLEDGMENTS

Dr. Estrela is thankful to FAPERJ, CAPES and FENORTE.

REFERENCES


Authors


Vania V. Estrela B.Sc. degree from Federal University of Rio de Janeiro (UFRJ) in Electrical and Computer Engineering (ECE); M.Sc. from the Instituto Tecnológico de Aeronáutica (ITA), Sao Jose dos Campos; M.Sc. degree in ECE at Northwestern University, Evanston, Illinois (IL), USA; and Ph.D. in ECE from the Illinois Institute of Technology (IIT). Taught at: DeVry University; DePaul University; Universidade Estadual do Norte Fluminense (UENF), Campos de Goytacazes, RJ, Brazil; Universidade Estadual da Zona Oeste (UEZO), RJ, Brazil, and Polytechnic Institute of Rio de Janeiro/State University of Rio de Janeiro in Nova Friburgo, RJ. Works for the Department of Telecommunications at Universidade Federal Fluminense (UFF), RJ, Brazil. Interests include: signal processing, inverse problems, computational & mathematical modeling, stochastic models, multimedia, motion estimation, machine learning, geo-processing, technology transfer, STEM education, environmental issues and digital inclusion. Reviewer for: IMAVIS; Pattern Recognition; COMPELECENG; IET Image Processing; IET Computer Vision, and Int’l Journal of Image Processing (IJIP). Member of IEEE, and ACM. Editor of IJIP.