R011-P07
ポスター 1 ：11/24　PM1/PM2 （13:15-18:15）

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Application of image processing techniques for monitoring the ionospheric environment: ionogram images

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The upper atmosphere, known as the ionosphere, can affect shortwave communications and cause satellite positioning errors. The structure of ionosphere is not stable and variable in the time of day, season, latitude, and solar activity, because of the differences of the energetic photo-ionization process. Ionosonde, which is a type of HF radar, widely used to monitor the ionospheric environment. Measuring the altitude distribution of electron density in the ionosphere, using High-Frequency radio wave reflections, often causes the low signal-to-noise ratio of ionospheric echoes due to radio frequency interference. This can cause difficulties in detecting ionospheric echoes from ionogram image, which visualizes the measured output of the ionosonde.

In this study, we propose the following two types of image processing techniques with respect to ionogram images, for tracing the ionospheric echoes from Ionogram: (1) a processing technique to convert an ionogram video image with a low signal-to-noise ratio into a noise-reduced image, and (2) a reconstruction technique for the intermediate image between two ionogram images.

For the converting technique (1), the proposed method consists of three processing parts: STEP1. noise removal optimized for individual Ionogram images, STEP2. extraction of ionospheric echoes by penalized background subtraction technique, and STEP3. fine-tuning of ionospheric echo signals using a minimum spanning tree algorithm. For unstable signal-to-noise-ratio Ionograms, the model automatically determines the boundary threshold between signal and noise using ridge regression for STEP1 and non-fixed penalized parameters for STEP2. The proposed model successfully reproduces fine Ionograms.

For the reconstruction technique (2), we applied morphing with Delaunay triangulation. Ten feature points of ionospheric echoes are selected from each of the two temporally separated ionogram images and an affine transformation is used to generate an intermediate image. We found this technique Effective for generating ionogram video images with short duration (1-hour) and small time variations.