Square to Hexagonal Lattice Conversion in the Frequency Domain

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Background

- Hexagonal Lattice in Nature

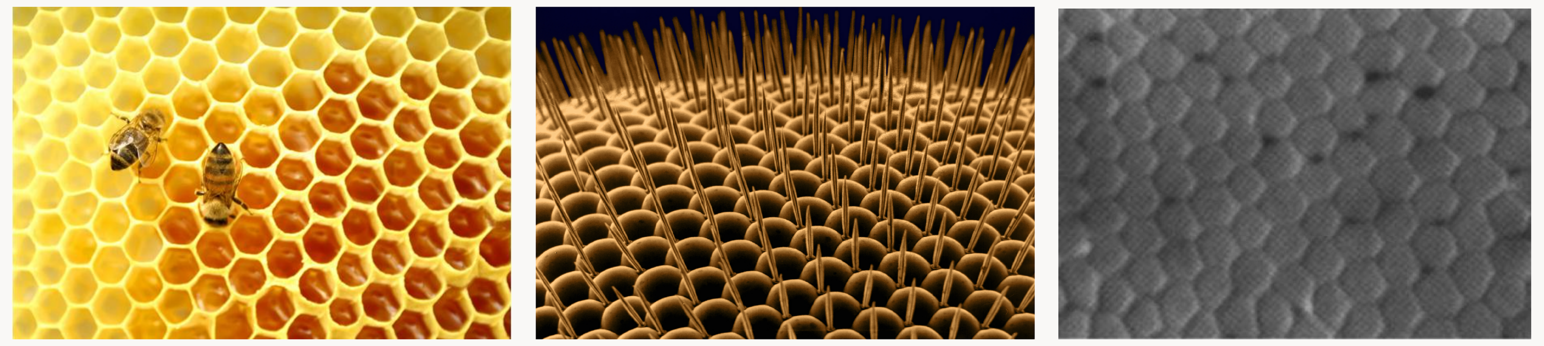

Figure 1: Examples of hexagonal lattice in the biological world. (left) honeycomb, (middle) insect compound eyes, and (right) human retina.

It is interesting that the hexagonal lattice is common in the digital image processing of biological vision systems.

- Hexagonal Lattice vs Square Lattice

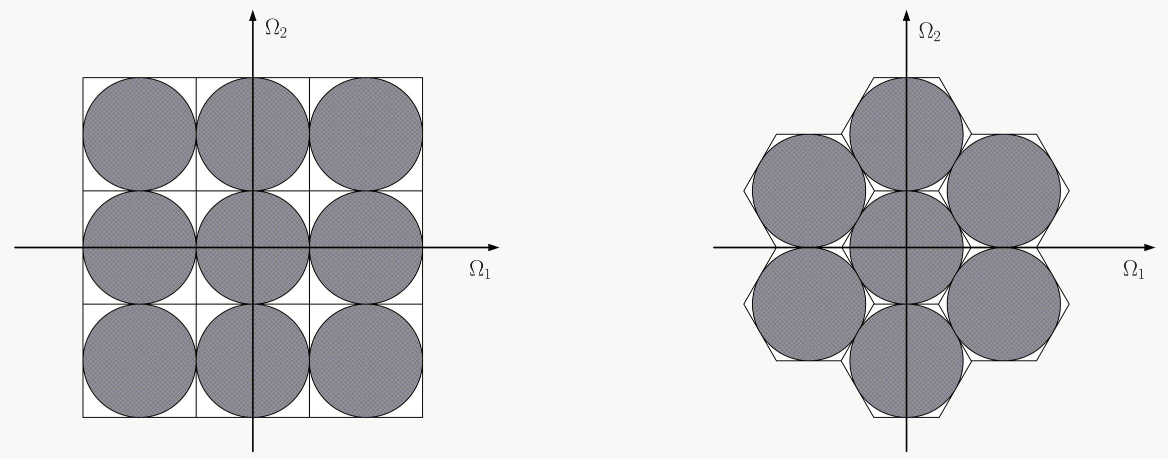

Figure 2: Comparison of the sampling efficiencies between the square lattice (left) and the regular hexagonal lattice (right).

- higher sampling efficiency

  fewer data means savings in both memory storage and computational cost.

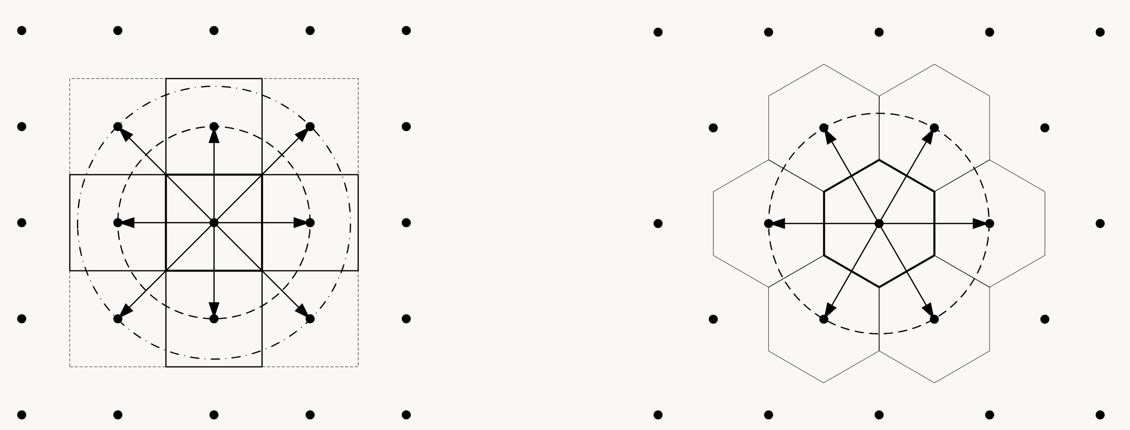

Figure 3: Comparison of the geometric properties between the square lattice (left) and the regular hexagonal lattice (right).

- higher degree of symmetry
- higher angular resolution
- equal distance with its neighbors
- uniform connectivity with its neighbors

Motivation

- practical imaging devices are predominantly based on the square lattice;
- hexagonal lattice data are obtained by resampling the original square lattice data;
- people often use simple interpolation kernels that may affect the processing performance;
- we need a method that can provide ground-truths to evaluate other conversion methods.

Proposed Ideal Conversion Method

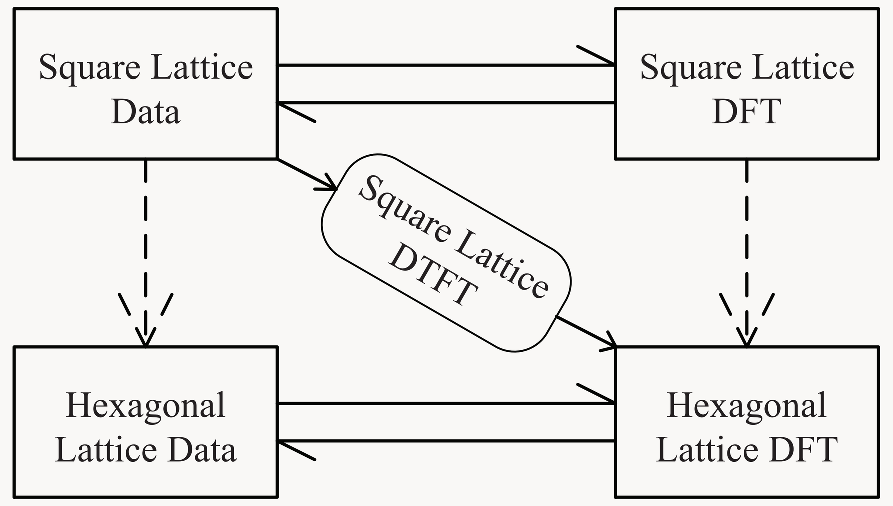

Figure 4: Illustration of the proposed method.

- common ideal conversion is by the sinc interpolation in the spatial or frequency domains;
- proposed ideal conversion computes each value of the HDFT through the square lattice DTFT.

Evaluating the Three Common Kernels

- Test Images from Laurent Condat's Image Database

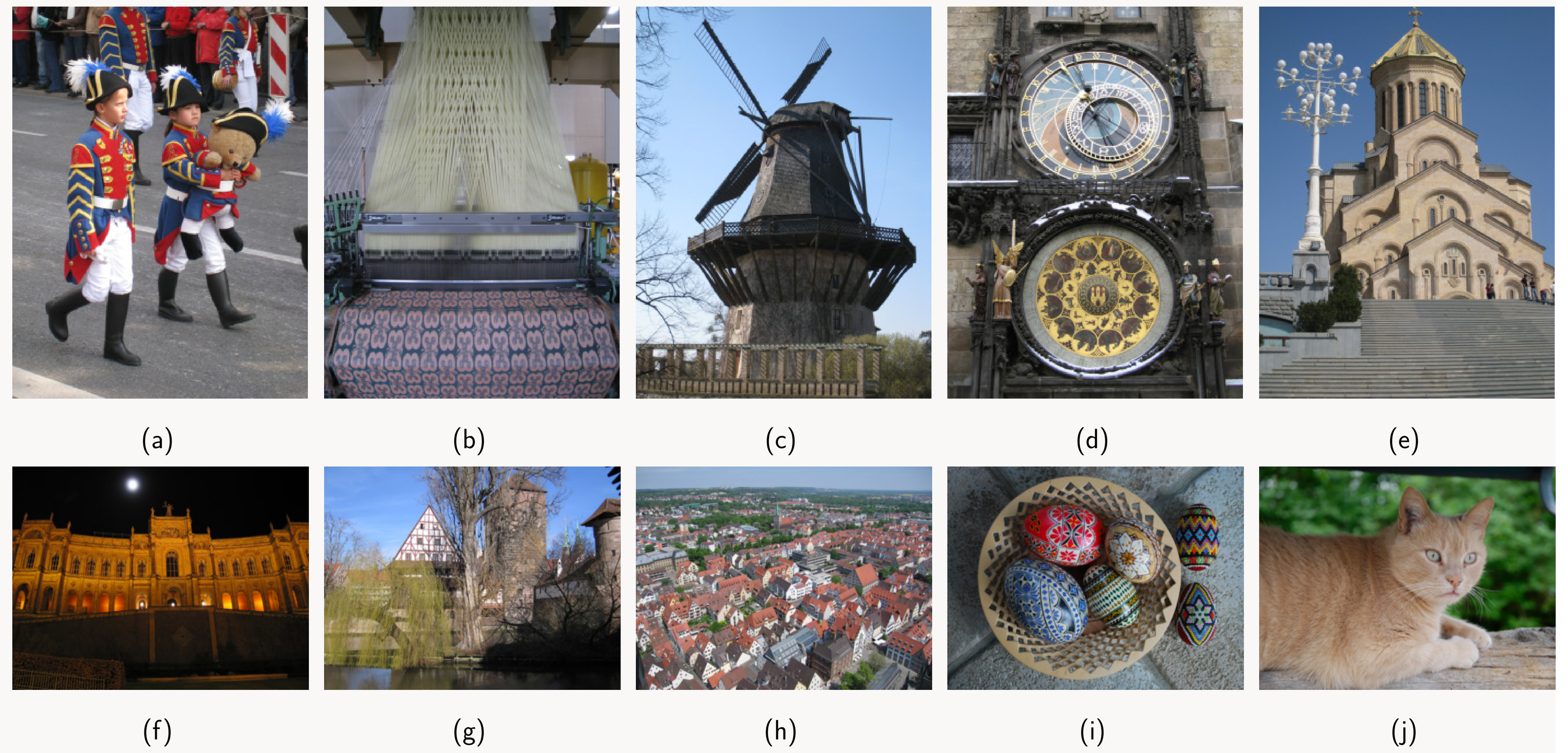

Figure 5: Test images used in the experiments. From (a) through (j): "IM002", "IM023", "IM052", "IM065", "IM077", "IM014", "IM035", "IM041", "IM127", "IM130", respectively.

- Visual Comparison of Conversion Difference with Three Typical Images

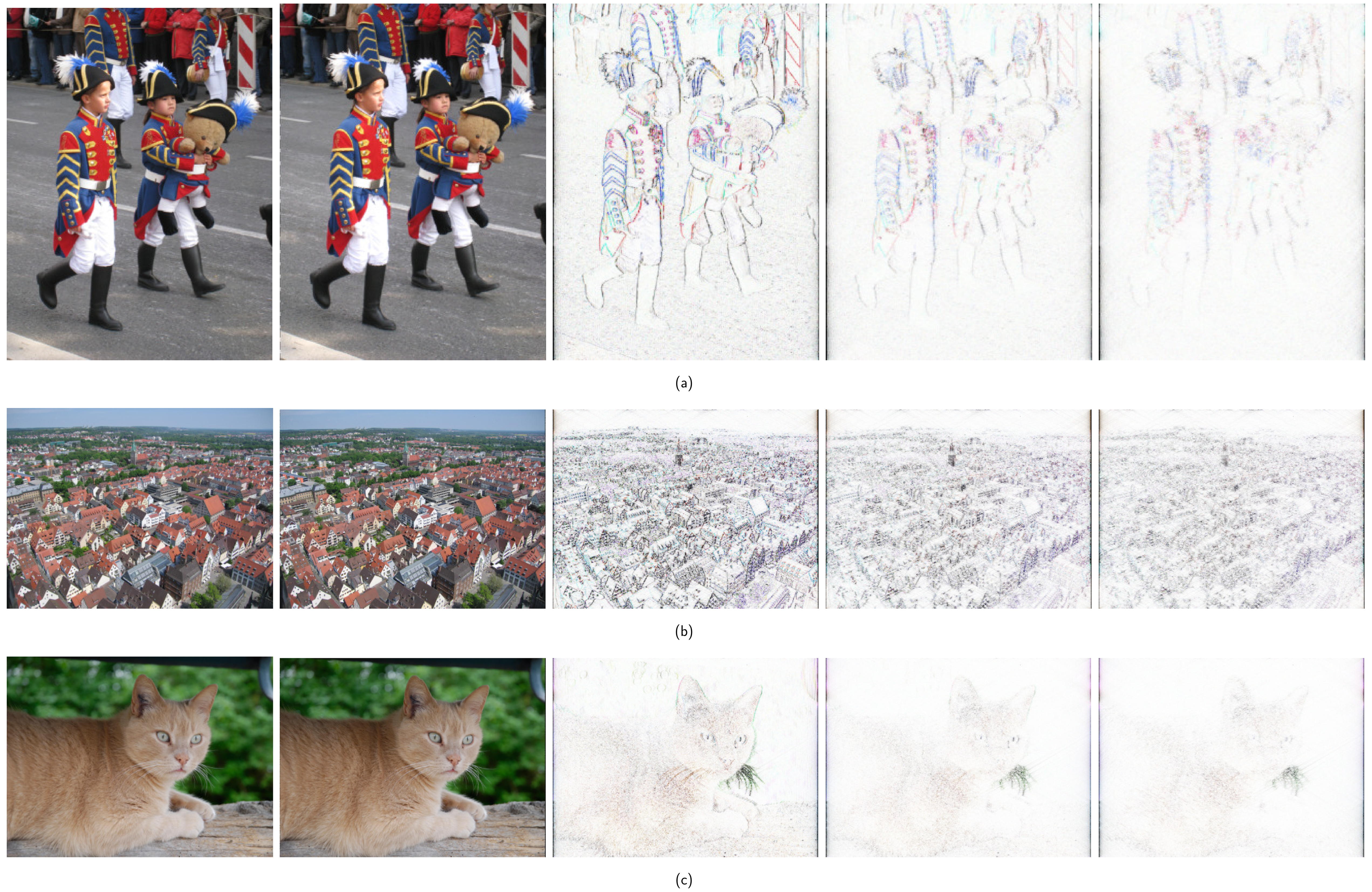

Figure 6: Illustration of the absolute errors ($\times 10$ and inverted) between the proposed ideal conversion method and the three common interpolation kernels with the three typical test images. (a) "IM002", (b) "IM041", and (c) "IM130". Each row, from left to right: the original test image, the ideally converted hexagonal lattice image, and then the absolute errors of "nearest-neighbor", "bilinear", and "bicubic", respectively.

- PSNR Results of Conversion Difference

Table 1: The PSNR (in dB) results of the evaluation experiments.

kernels \ test images	"IM002.tif"	"IM023.tif"	"IM052.tif"	"IM065.tif"	"IM077.tif"	"IM014.tif"	"IM035.tif"	"IM041.tif"	"IM127.tif"	"IM130.tif"
"nearest-neighbor"	35.3313	34.2255	31.9119	31.7340	34.0174	37.3021	30.1346	29.9663	30.7593	39.9978
"bilinear"	42.0143	39.4381	37.0771	37.6169	38.5320	42.0640	34.4484	35.1178	36.8227	45.2878
"bicubic"	44.5362	41.9161	38.6962	39.8090	40.2184	44.4166	36.2190	37.2844	39.8188	46.8872