

# Sample 13-2

## 辞書学習

再構成独立成分分析

画像処理特論

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動作確認: MATLAB R2020a

## Dictionary learning

Reconstruction ICA

Advanced Topics in Image Processing

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Verified: MATLAB R2020a

## 準備

(Preparation)

```
clear
close all
import msip.download_img
msip.download_img
```

```
lena.png already exists in ./data/
baboon.png already exists in ./data/
goldhill.png already exists in ./data/
barbara.png already exists in ./data/
```

## パラメータ設定

(Parameter settings)

- ブロックサイズ (Block size)
- 冗長率 (Redundancy ratio)
- 繰返し回数 (Number of iterations)
- 正則化パラメータ (Regularization parameter)

```
% Block size
szBlk = [ 8 8 ];
nDims = prod(szBlk);

% Redundancy ratio
redundancyRatio = 1.5;

% Number of iterations
```

```
nIters = 1000;

% Regularization parameter
alpha = 0.5;
```

## 画像の読込

(Read image)

$$\bullet \mathbf{u} \in \mathbb{R}^N$$

```
u = rgb2gray(im2double(imread('./data/lena.png')));
```

## 再構成独立成分分析

(Reconstruction ICA)

問題設定 (Problem setting):

$$\begin{aligned}\widehat{\Phi} &= \arg \max_{\Phi} \frac{1}{2S} \sum_{n=1}^S \|\mathbf{y}_n - \Phi \Phi^T \mathbf{y}_n\|_2^2 + \frac{\alpha}{S} \sum_{n=1}^S \rho(\Phi^T \mathbf{y}_n) \\ &= \arg \max_{\Phi} \frac{(2\alpha)^{-1}}{S} \sum_{n=1}^S \|\mathbf{y}_n - \Phi \Phi^T \mathbf{y}_n\|_2^2 + \frac{1}{S} \sum_{n=1}^S \rho(\Phi^T \mathbf{y}_n)\end{aligned}$$

ただし,  $\{\mathbf{y}_n\}_n \subset \mathbb{R}^M$ ,  $\Phi = (\phi_1, \phi_2, \dots, \phi_P) \in \mathbb{R}^{M \times P}$ ,  $M \geq P$  である. (where,  $\{\mathbf{y}_n\}_n \subset \mathbb{R}^M$  and  $\Phi = (\phi_1, \phi_2, \dots, \phi_P) \in \mathbb{R}^{M \times P}$ ,  $M \geq P$ .)

参考文献 (Reference):

Le, Quoc V., Alexandre Karpenko, Jiquan Ngiam, and Andrew Y. Ng. "ICA with Reconstruction Cost for Efficient Overcomplete Feature Learning." Advances in Neural Information Processing Systems. Vol. 24, 2011, pp. 1017–1025. <https://papers.nips.cc/paper/4467-ica-with-reconstruction-cost-for-efficient-overcomplete-feature-learning.pdf>.

画像  $\mathbf{u}$  からのデータ行列  $\mathbf{Y}$  の生成 (Generation of data matrix  $\mathbf{Y}$  of image  $\mathbf{u}$ )

```
Y = im2col(u, szBlk, 'distinct');
```

コントラスト関数の例 (Example of contrast function)

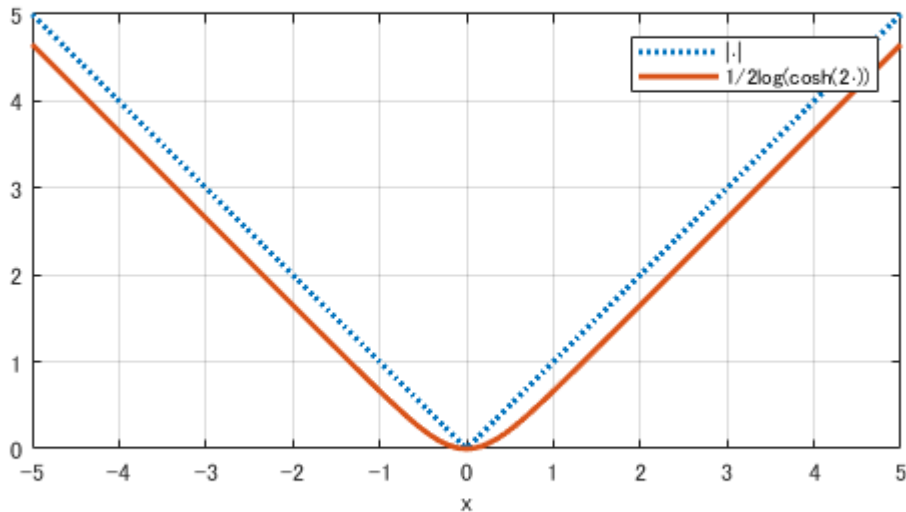
$$\rho(\Phi^T \mathbf{y}) := \frac{1}{2} \sum_{p=1}^P \log \circ \cosh(2\phi_p^T \mathbf{y})$$

```
figure(1)
fplot(@(x) abs(x), [-5 5], ':', 'LineWidth', 2, 'DisplayName', '| \cdot |')
```

```

hold on
fplot(@(x) log(cosh(2*x))/2,[-5 5],'-','LineWidth',2,'DisplayName','1/2log(cosh(2\cdot))')
xlabel('x')
legend
grid on
axis equal
hold off

```



要素画像の数 (Number of atomic images)

```
nAtoms = ceil(redundancyRatio*nDims);
```

辞書  $\Phi$  の初期化 (Initialization of dictionary  $\Phi$ )

- 二変量離散コサイン変換(Bivariate DCT)
- ランダム (random)

```

Phi = randn(nDims,nAtoms);
Phi = Phi/norm(Phi,'fro');
for iAtom = 1:nDims
    delta = zeros(szBlk);
    delta(iAtom) = 1;
    Phi(:,iAtom) = reshape(idct2(delta),nDims,1);
end

```

要素ベクトルを要素画像に変換 (Reshape the atoms into atomic images)

```
atomicImages = zeros(szBlk(1),szBlk(2),nAtoms);  
for iAtom = 1:nAtoms  
    atomicImages(:,:,iAtom) = reshape(Phi(:,iAtom),szBlk(1),szBlk(2));  
end
```

## 画像表示

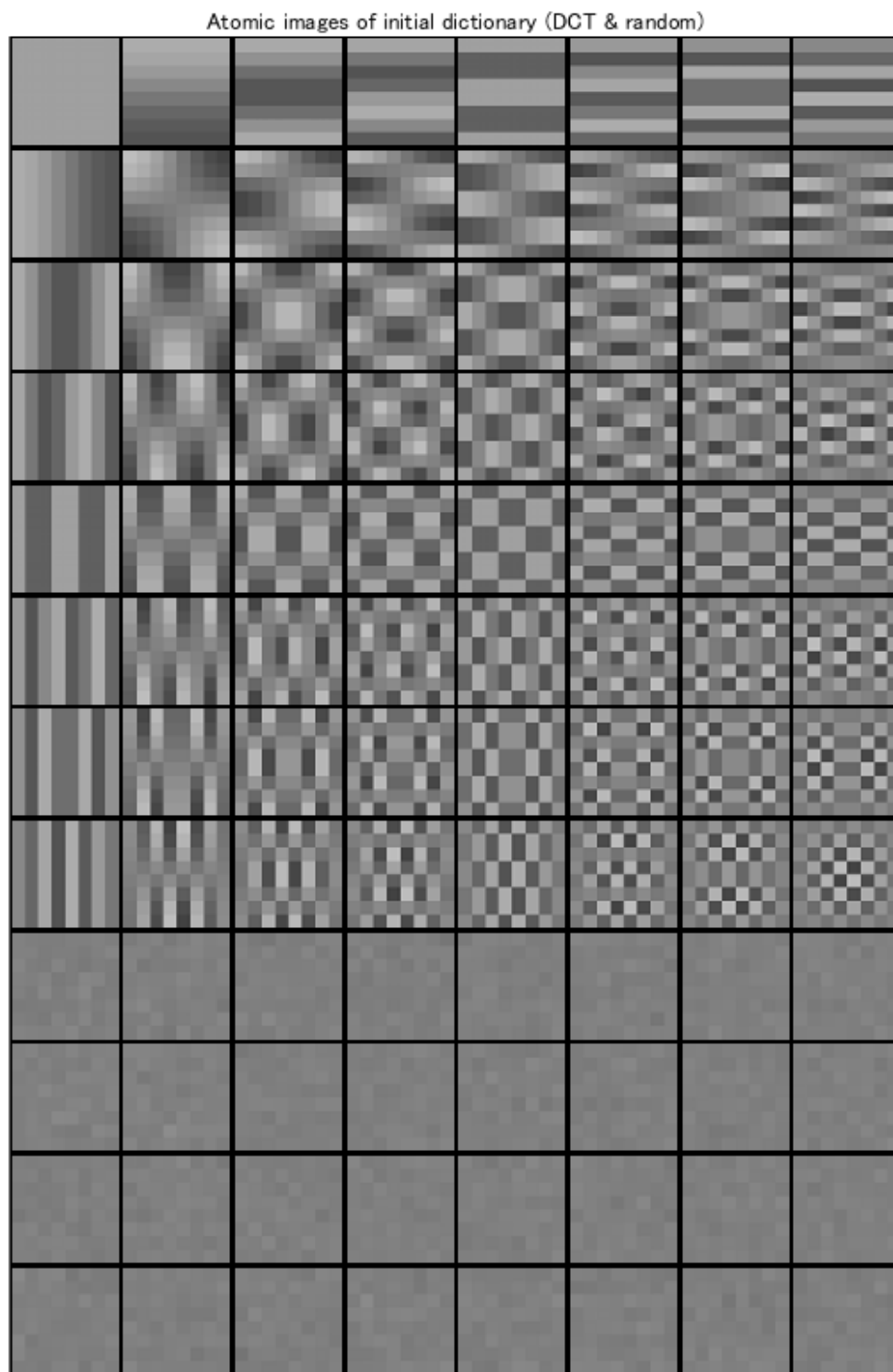
(Image show)

```
figure(2)  
imshow(u);  
title('Original image u')
```



```
figure(3)  
montage(imresize(atomicImages,8,'nearest')+.5,'BorderSize',[2 2],'Size',[ceil(nAtoms/8) 8])
```

```
title('Atomic images of initial dictionary (DCT & random)')
```



再構成 ICA オブジェクトの作成 (Creation of reconstructio ICA object)

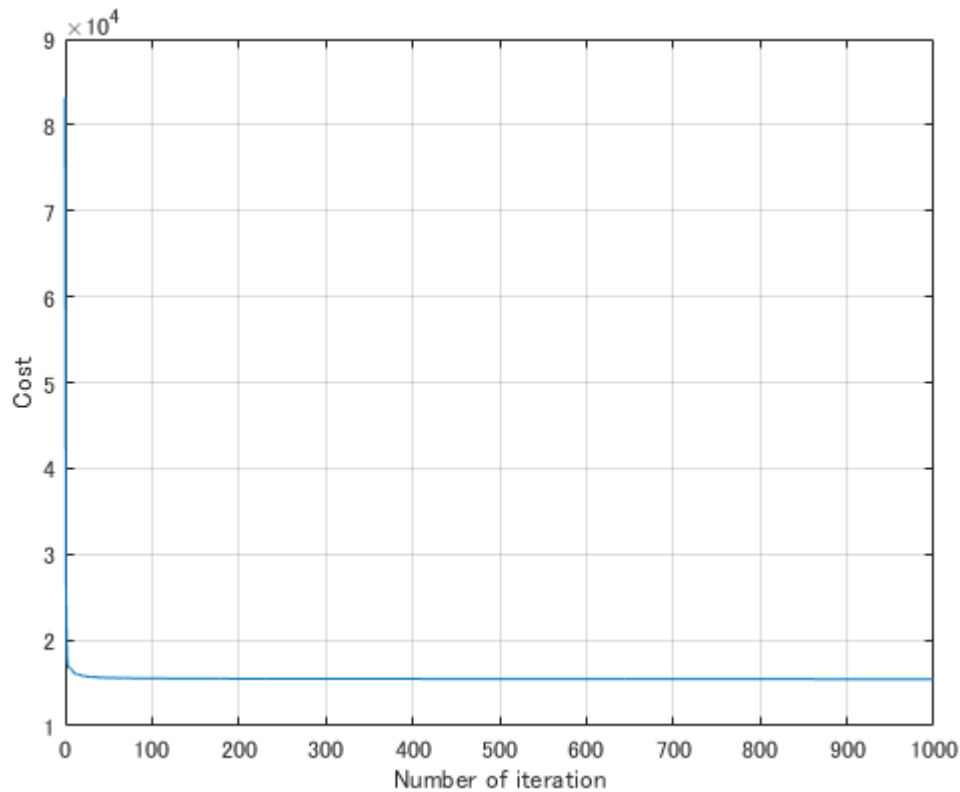
```
model = rica(Y.',nAtoms,...  
            'IterationLimit',nIters,...
```

```
'ContrastFcn','logcosh',...
'InitialTransformWeight',Phi,...
'Lambda',1/(2*alpha));
```

警告: ソルバー LBFGS は解に収束できませんでした。

コスト評価のグラフ (Graph of cost variation)

```
info = model.FitInfo;
figure(4)
plot(info.Iteration,info.Objective)
xlabel('Number of iteration')
ylabel('Cost')
grid on
```



要素ベクトルを要素画像に変換 (Reshape the atoms into atomic images)

```
Phi = model.TransformWeights;
atomicImages = zeros(szBlk(1),szBlk(2),nAtoms);
for iAtom = 1:nAtoms
    atomicImages(:,:,iAtom) = reshape(Phi(:,iAtom),szBlk(1),szBlk(2));
end
figure(5)
montage(imresize(atomicImages,8,'nearest')+0.5,'BorderSize',[2 2],'Size',[ceil(nAtoms/8) 8])
title('Atomic images of RICA')
```

Atomic images of RICA

