The University of Western Ontario
Computer Science CS9630a
Final Examination - December 4th, 2012

Surname
Given Name
Student Number

This exam consists of 5 questions (9 pages, including this page) worth a total of 100%. It is an open book exam. All answers are to be written in this booklet. Scrap work may be done on the back of each page; this will not be marked. The exam is 2 hours long and comprises 30% of your final mark. Assignments 1 and 2 are each worth 35% respectively, for a total of 70%.

(1) 20%
(2) 20%
(3) 20%
(4) 20%
(5) 20%
Total

Professor: John Barron
Answer the following questions briefly and concisely and show all relevant work. Where possible, use point-form. Generally, correct answers will be short.

(1) (20%) Give examples of functions (with pictures) satisfying the following:

1. The FT of a discrete signal is a continuous signal:

2. the FT of a continuous signal is a discrete signal:

3. The FT of a discrete signal is a discrete signal:

4. the FT of a continuous signal is a continuous signal:
(2) (20%) Consider $3 \times 3$ median filtering and histogram equalization. Which of these 2 methods is best for suppression of Salt and Pepper noise in the spatial domain and why?
Figure 1: (a) the input image 630image.ras and (b) the transformed image.

3 (20%) The MatLab code below computes the image in Figure 1b from the image in Figure 1a.

```matlab
% 630image.ras is a 256*256 version of the Yosemite image
f=double(imread('630image.ras'));
figure
imshow(f,[]);
title('Original 630image');
print('-deps','630image.eps');

F=fft2(fftshift(f));
u=-1/2:1/256:1/2-1/256;
v=-1/2:1/256:1/2-1/256;

for a=1:256
    for b=1:256
        F1(a,b)=-4*pi*pi*(u(a)^2)*F(a,b);
    end
end
```
f=ifftshift(ifft2(F1));
figure
imshow(real(f),[]);
title('Transformed 630 image');
print('-deps','630transformed.eps');

(3a) (10%) Write vectorized MatLab code for the loop in the above code. You may want to use \texttt{repmat} which can duplicate rows or volumes of a Matrix. For example, \texttt{repmat([0 1; 1 0],2,3)} converts matrix:

\begin{align*}
0 & & 1 \\
1 & & 0
\end{align*}

into the matrix:

\begin{align*}
0 & & 1 & & 0 & & 1 & & 0 & & 1 \\
1 & & 0 & & 1 & & 0 & & 1 & & 0 \\
0 & & 1 & & 0 & & 1 & & 0 & & 1 \\
1 & & 0 & & 1 & & 0 & & 1 & & 0
\end{align*}

Answer for (3a) here and continued on the next page:
(3b) (5%) The above MatLab program has the number 256 occurring many times. 256 is either the row or column dimension of the image. How would you generalize the code that computes $u$ and $v$ to handle any row and column image dimensions?

(3c) (5%) What transformation does this image compute on the input image?
(4) (20%) Consider the following MatLab code and the morphological operators: erosion and dilation. Figures 2a and 2b shows the original Woman Silhouette image and its flipped version (1’s changed to 0 and 0’s changes to 1’s) so that erosion and dilation work as you would expect. Figures 2c to 2f show the 4 images that result when the flipped image is subjected to double erosion, double dilation, erosion followed by dilation or dilation follow by erosion using one of two structuring elements:

\[
B_1 = \begin{pmatrix}
1 & 1 & 1 \\
1 & 1 & 1 \\
1 & 1 & 1
\end{pmatrix} \quad B_2 = \begin{pmatrix}
0 & 0 & 0 \\
0 & 1 & 0 \\
0 & 0 & 0
\end{pmatrix}
\]

Answer the following questions for the Flipped Woman by specifying the 2 morphological operators (erode, dilate), (dilate, erode), (erode, erode) and (dilate, dilate) used to generate the images and the structuring elements used by each operator:

(4a) (5%) The $f_{1_1}$ image

(4b) (5%) The $f_{1_2}$ image

(4c) (5%) The $f_{2_1}$ image

(4d) (5%) The $f_{2_2}$ image
Figure 2: Original Woman images, its flipped version and 4 images $f_{11}$ to $f_{22}$ resulting from the double application of erode and dilate operations using structuring elements $B1$ and $B2$. 
(5) (20%) Consider a 1D signal (image), $f(x)$, $x \in [1, 128]$. We are given its centered Fourier transform as 128 $F(u)$ values, indexed by 1 to 128. Suppose the spatial signal, $f(x)$, is subsampled by 6. Show all your calculations.

1. What is the minimum frequency represented in $F(u)$?

2. What is the maximum frequency represented in $F(u)$?

3. What is the frequency at index 32 in $F$?

4. What is the formula to compute the Fourier transform value for $f(32)$? [Do not do the arithmetic.]