Defensive coding in MATLAB

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This is not really about defensive coding



- "Defensive coding" (officially) = protecting your programs from incompetent or malicious user input
- BUT we still want to minimize bugs and write code others can understand (= standards and style)
- For stimulus generation and data analysis, there are additional considerations like measurement units and parameter logging
- MATLAB is more forgiving than standard programming languages, but this sometimes makes bugs harder to spot

What might badly-written code look like?



General concepts

- Divide programs into logically-sound chunks, using functions if necessary
- Make variable and function names consistent and informative
- Try not to repeat code
- Save all parameters
- Timestamp outputs to avoid overwriting
- Document what the code DOESN'T say
- Conventions in this presentation:
 blue = code, green = comments, red = strings







Variables

- Make names informative and include units
 - timeMS, targetSizePix, frameRateHz, screenResolutionPixPerDeg
- Captalization conventions
 - variables start with lower case: fixationDurationSec
 - functions have the first letter capitalized: ComputeDistribution()
 - constants are in all caps: DEBUG_MODE = 1;
- Prefixes n for number and i for counter
 - **for** iTrial = 1:nTrial,
- CamelCase vs Underscore_method
 - Be consistent: I prefer CamelCase with underscores for constants
- Avoid overwriting MATLAB functions (length, which, log, ...)
- Define constants only ONCE, at the top of the code



Comments

- Header comments are for users, code comments for programmers
- Comment liberally, but make them informative
 x = x + 1; % add one to x (this is not a useful comment)
 x = x + 1; % add one to compensate for MATLAB indexing (better)
- Uses double comments to mark section boundaries %% initialize user parameters %% real-time display loop
- Comment loop ends
 - for iTrial = 1:nTrial,
 for iFrame = 1:nFrame,
 <3 pages of draw code>
 end % for iTrial = 1:nTrial,
 end % for iFrame = 1:nFrame,



Comments and functions



• Documenting function example

function [dotXdeg, dotYdeg, colorList, nDots] = ... GenerateDotFieldSq(squareSideDeg, dotDiamDeg, ... dotDensityPerDeg2, blackProb, debugFlag)

% generate probabilistic dot field, with checks to eliminate overlaps

% NOTE: overlap avoidance will silently fail if too many iterations needed (currently >1E6)

% INPUT squareSideDeg = size of dot field (etc.)

% OUTPUT dotXdeg = horizontal positions of all dots (etc.)

Functions and structures

- Consider structures if you have many parameters patient = []; % initialize as empty (not struct[]!) patient.name = 'John Doe'; patient.billing = 127.00; patient.test = [79, 75, 73; 180, 178, 177.5; 220, 201, 205];
- **function** updatedPatient = ...

AddNewDataToPatient (newData, patient) function drawSingleFrame(stimulusParameters)





Parameters

- Define parameters up top, in structure
 params.dotDiamDeg = 0.26; % base dot size
 params.dotDensityPerDeg2 = 2.0; % #dots per sq deg
- <set up PTB screen window, etc>
- params.derived.screenCtrPix = screenCtrPix; % substructure
- params.derived.programName = mfilename; % returns name of m-file
 <run single trial>
- save (saveFileName, 'params', 'data', '-append'); % save after every trial



Randomizing



- Balanced, independent or joint?
 - Balanced assures all conditions are presented equally often, but can cause issues with predictability
 - Joint balanced assures parameter combinations are equally represented
 - True independent will create unequal group sizes that inconvenience statistical analysis
- Balanced independent:
 - Total trials nTrials multiple of nParamA * nParamB * nParamC *.....
 - Use randperm() to index the matrix randIdx = randperm(nTrials); % shuffle

paramA_TrialIdxList = rem(randIdx-1, nParamA) + 1; % vector of index values into ParamA

Randomizing continued

- Balanced joint:
 - Parameter A (n=2) 1 2 1 2 1 2 1 2 1 2 1 2
 - Parameter B (n=2) 1 1 2
 - Parameter C (n=3) 1 1 1 1 2 2 2 2 3 3 3

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- Use repmat() to create and randperm() to index the matrix
- True independent:
 - "sampling with replacement"

randIdx = randi(nParams, nTrials, 1); % directly indexes your parameter

Refresh the randomizer and save the seed!
 randState = rng('shuffle'); % refresh random generator based on current time



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Data logging

- Initialize a matrix of responses
 - E.g., response latency, response key
 - Should be in register with trial parameters!
 - For variable-length data:
 - Allocate extra space now and trim at end
- Write data at end of each trial (after all gfx)
 - Save every trial in case of crash
 - For large data:
 - You can sometimes just save the random seed (e.g., 800x800x3 noise mask texture)
 - Consider separate matrices:
 eval(sprintf('trialDataMatrix%.3d = currentTrialDataMatrix;', iTrial)); % e.g. trialDataMatrix006
 - Convention: longest dimension as rows (trial number or sample time)

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Optimization

- In the PTB draw loop, all operations need to be completed within one frame (~16 ms)
- Modern computers are fast and forgiving, but certain operations still take a lot of time:
 - Initializing new variables
 - First-time function calls
 - Concatenating arrays and matrices
 - Creating textures
 - Writing to disk
- Move as much as possible out of the draw loop!



Optimization example

randState = rng;



% save current state of random number generator

xyPosPix = stepSizePix * cumsum(randn(nFrames, 2));
% generate positions for 2-D random walk

noiseCoreTex = Screen('MakeTexture', winPtr, noiseCore);
% create an offscreen texture using a previously created matrix

t0 = GetSecs; t1=t0; t2=t0; t3=t0;

% initialize the timer variables we will use for consistency checks

Priority(MaxPriority(winPtr));

% set maximum execution priority

Optimization example continued

%% now we are ready to start the display loop



vbl=Screen('Flip', winPtr); % do initial flip to synchronize

- t0 = vbl; % save starting time
- for iFrame = 1:nFrame,

Screen('DrawDots', winPtr, xyPosPix(iFrame,:), dotSizePix);

Screen('DrawingFinished', winPtr);

<handle user input, etc. here if necessary>

vbl=Screen('Flip', winPtr, vbl + (waitFrames-0.5)*ifi);

- end % for iFrame = 1:nFrame,
- t1 = GetSecs t0; % elapsed time of all frames

Protecting from users

• Check inputs

if isempty(userInput), <execute some contingency>; end
if userInput < minAllowed || userInput > maxAllowed,

<execute some contingency>; end



if numel(userInputString) > maxAllowed, userInputString =
 userInputString(1:maxAllowed); end

• Function argument counts

function MyFun(criticalInput1, criticalInput2, optionalInput3)

% remember to put your help/instruction text here!

if nargin < 3, input3 = <some default value>; end

if nargin < 2, help (mfilename); return; end % displays help & aborts execution

Protecting from everyone

- Sometimes code crashes
 - Because of users, programmers or computers having a bad day
- This is annoying in Psychtoolbox because of screen windows, etc.

try

< do complicated psychtoolbox stuff>

catch

Priority(0); % ramp down the priority if it was elevated
 ShowCursor; % restore the cursor if it was hidden
 ListenChar(0); % stop character checking and reenable keyboard echos
 sca; fclose all; % close any open windows, textures, files
 rethrow(lasterror); % display the error that caused the crash
 end % could also save data here, but you don't need to because you save every trial, right?



Miscellaneous tips

• Indent loops and conditionals!



- Avoid if possible break and continue in loops, as they make it difficult to check flow control
 - Consider using a while loop: while iTrials <= nTrials && ~abortCondition,
- Use parentheses for mathematical expressions
- Break long lines with ellipsis (...)
- Don't be afraid to use spaces between operators for readability
- Use a leading zero if necessary when writing decimals

• x = 0.5;

saveFilename = sprintf('%s_%s', mfilename, subjCode, datestr(now, 30)); % generate a safe file name

Acknowledgements

- Unakafova, V. A. (2017). Best practices for scientific computing and MATLAB programming style guidelines. 10.13140/RG.2.2.32109.18408.
- Wilson, G., et al. "Best practices for scientific computing." PLoS Biol 12.1 (2014): e1001745. (as cited in Unakafova)
- Johnson, R., "Matlab programming style guidelines." USA Datatool. Version 1 (2002) 2.1 updated version at <u>http://www.datatool.com/downloads/MatlabStyle</u> <u>2%20book.pdf</u> (as cited in Unakafova)
- Giovanni Fusco, Smith-Kettlewell Eye Research Institute, San Francisco



Good Luck!

