Timescales Toolbox for MatLab

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Objective

A detailed debugging process was developed with the goal of strenuously testing the developed functions in the "Time Scale Toolbox for MatLab" for errors, and to produce a second version of the toolbox with the corrected errors to be posted on the timescales.org website.

Plan of Implementation

Develop scripts that use the time scale constructor to generate a series of continuous and discrete time scales with as many possible types including:

- small single interval time scale with few terms
- small single interval time scale with many terms
- large single interval time scale with few terms
- large single interval time scale with many terms
- small multi interval time scale with few terms
- small multi interval time scale with many terms
- large multi interval time scale with few terms
- large multi interval time scale with many terms
- small single interval empty time scale
- large single interval empty time scale
- small multi interval empty time scale
- large multi interval empty time scale
- time scale with an empty set

Here are some screen captures that demonstrate some of the sample scripts, for both the continuous and discrete types, that I generated for testing the time scales functions:
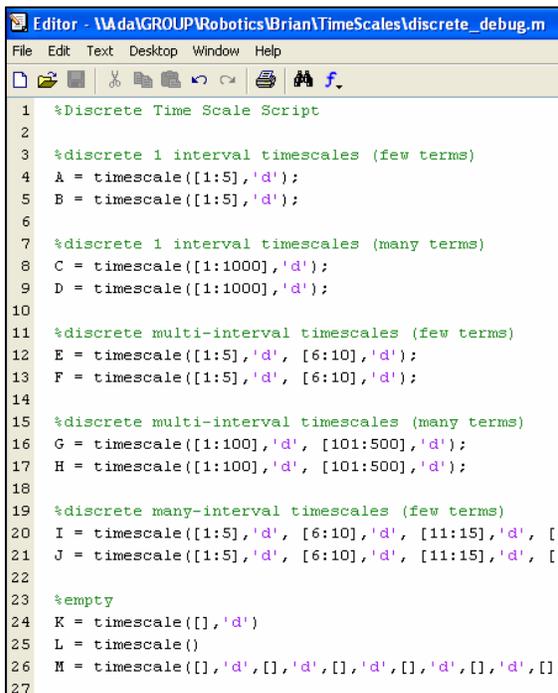
```
Editor - \\Ada\GROUP\Robotics\Brian\TimeScales\discrete_debug.m
File  Edit  Text  Desktop  Window  Help

1    %Discrete Time Scale Script
2
3    %discrete 1 interval timescales (few terms)
4    A = timescale([1:5],'d');
5    B = timescale([1:5],'d');
6
7    %discrete 1 interval timescales (many terms)
8    C = timescale([1:1000],'d');
9    D = timescale([1:1000],'d');
10
11   %discrete multi-interval timescales (few terms)
12   E = timescale([1:5],'d', [6:10],'d');
13   F = timescale([1:5],'d', [6:10],'d');
14
15   %discrete multi-interval timescales (many terms)
16   G = timescale([1:100],'d', [101:500],'d');
17   H = timescale([1:100],'d', [101:500],'d');
18
19   %discrete many-interval timescales (few terms)
20   I = timescale([1:5],'d', [6:10],'d', [11:15],'d', [1
21   J = timescale([1:5],'d', [6:10],'d', [11:15],'d', [1
22
23   %empty
24   K = timescale([],'d')
25   L = timescale()
26   M = timescale([],'d',[],'d',[],'d',[],'d',[],'d',[],
27
```
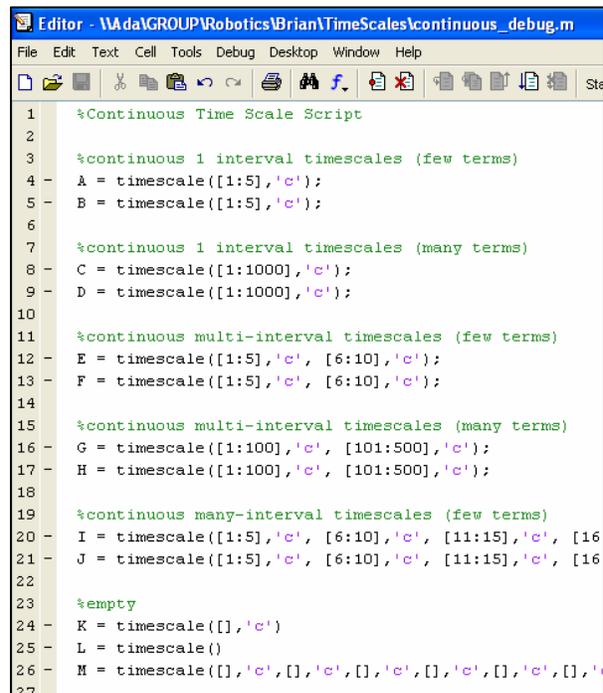
```
Editor - \\Ada\GROUP\Robotics\Brian\TimeScales\continuous_debug.m
File  Edit  Text  Cell  Tools  Debug  Desktop  Window  Help

1    %Continuous Time Scale Script
2
3    %continuous 1 interval timescales (few terms)
4    A = timescale([1:5],'c');
5    B = timescale([1:5],'c');
6
7    %continuous 1 interval timescales (many terms)
8    C = timescale([1:1000],'c');
9    D = timescale([1:1000],'c');
10
11   %continuous multi-interval timescales (few terms)
12   E = timescale([1:5],'c', [6:10],'c');
13   F = timescale([1:5],'c', [6:10],'c');
14
15   %continuous multi-interval timescales (many terms)
16   G = timescale([1:100],'c', [101:500],'c');
17   H = timescale([1:100],'c', [101:500],'c');
18
19   %continuous many-interval timescales (few terms)
20   I = timescale([1:5],'c', [6:10],'c', [11:15],'c', [16
21   J = timescale([1:5],'c', [6:10],'c', [11:15],'c', [16
22
23   %empty
24   K = timescale([],'c')
25   L = timescale()
26   M = timescale([],'c',[],'c',[],'c',[],'c',[],'c',[],'
27
```

Criteria for Testing

After developing a script to generate all the reasonable possibilities for time scale constructions, I developed a systematical procedure for debugging each function with the "Time Scale Toolbox".

Here is my procedural guideline for debugging each function:

1. **Check for grammatical errors**
    a. Read through the entire function, especially the help sections and information designed for users, for grammatical errors and typos.

2. **Verify the validity of the help section**
    a. Does the help section actually explain how to use the function?
    b. How can the help be improved?

3. **Logical understanding of each function**
    a. Step through each function line by line, developing an understanding for variables and commands on those variables
    b. Try to make sense of the function from a coding perspective

4. **Execute the function**
    a. Test the function with each possible time scale generated from the scripts
    b. Generate every possible expected result to verify that the function produces the correct answer
    c. Generate every possible error message that the function is designed to produce to verify correct error checking
    d. Give close attention to empty set and empty interval time scale types

Execution

There are 19 functions to operate on time scales in the "Timescale" folder as well as an additional 41 functions that are classes, constructors, or overloads of time scales in the "@timescale".

Given the total of 60 functions to debug over the course of one semester, I determined a pace of debugging 4-5 functions a week, understanding that some functions will naturally take a longer time to debug than others.

Debugged Functions:

@timescale folder

abs.m	isdiscrete.m	power.m
and.m	le.m	rdivide.m
angle.m	length.m	real.m
conj.m	log.m	sin.m
cos.m	lt.m	size.m
display.m	min.m	sqrt.m
eq.m	minus.m	subsasgn.m
exp.m	mpower.m	subsref.m
find.m	mrdivide.m	tan.m
ge.m	mtimes.m	times.m
gt.m	ne.m	timescale.m
horzcat.m	not.m	uminus.m
imag.m	or.m	vertcat.m
incompatible.m	plus.m	

timescale folder

oderecursive.m	tsfind.m	tsplot.m
recursive.m	tsforward.m	tsqz.m
tsbackward.m	tsharmonic.m	tssin.m
tscircminus.m	tsmu.m	tssinh.m
tscos.m	tsnu.m	tszeros.m
tscosh.m	tsode.m	
tsexp.m	tspab.m	

Changes to Functions

Note: "help section format" includes the following changes:
- formatting the help section for each function to duplicate the general MatLab format for help sections
- insertion of carriage returns to prevent running over text and create easier readability

@TIMESCALE FOLDER

abs.m
- help section format

and.m
- help section format

angle.m
- help section format

conj.m
- help section format
- addition of period
- provide original author information (Ian Gravagne, Date, Baylor University)

cos.m
- help section format
- addition of the word "the" in help section

display.m
- help section format
- grammatical error in help section
  - % Displays an timescale object A.
  - % Displays a timescale object A.

eq.m
- help section format

exp.m
- help section format

find.m
- help section format

ge.m
- help section format

gt.m
- help section format

horzcat.m
- help section format

imag.m
- help section format

incompatible.m
- help section format

isdiscrete.m
- help section format
- capitalization of beginning of sentence
- change 'zeros' to 0's for consistency with 1's

le.m
- help section format

length.m
- help section format

log.m
- help section format

min.m
- help section format
- provide original author information (Ian Gravagne, Baylor University)

minus.m
- help section format

mpower.m
- help section format

mrdivide.m
- help section format
- spelling error on output
  - error('Timescale divide A/B requires A to be a scalar.');

mtimes.m
- help section format

ne.m
- help section format

not.m
- help section format

or.m
- help section format

plus.m
- help section format

power.m
- help section format
- grammatical sentence structure
    - Also works if either argument is a scalar.

rdivide.m
- help section format
- inserted a portion of coding that allows for actual element by element division between two timescale objects
    - required correction of logic statements
- spelling error on output
    - error('Timescale divide A/B requires A to be a scalar.');

real.m
- help section format

sin.m
- help section format

size.m
- help section format
- spelling error in help section
    - % the number of (continuous and/or discrete) invtervals in the timescale.
    - % the number of (continuous and/or discrete intervals in the timescale.
- deletion of the word "and"
- capitalization of the word "interval" to begin a new sentence
- grammar error in help section
    - Users may construct a size matrix and associate it with a vector of data points using the timescale constructor.

sqrt.m
- help section format

subasgn.m
- help section format
- replace all references to intervals as 'n' with 'k' for consistency
- correction on output for all other cases
    - error('Timescale assignment could not be interpreted. See HELP timescale/subsasgn.')

subsref.m
- help section format
- spelling error on error check comment
    - %%% PRELIMINARY ERROR CHECK %%%
- addition of clarity on comment
    - Parenthesis dereference handler

tan.m
- help section format

times.m
- help section format

timescale.m
- help section format

uminus.m
- help section format

vertcat.m
- creation of a help section

TIMESCALE FOLDER

oderecursive.m
- help section format

recursive.m
- help section format

tsbackward.m
- help section format

tscircminus.m
- help section format
- changes to help section to include the theorem for calculation
  - TSCIRCMINUS(z,T) is implemented using the form specified by Theorem 2.7 of Dynamic Equations on Time Scales by Bohner-Peterson.

    The Theorem states the circle minus operator as given below:

    circle minus z = -z / (1 + z*h)

    where z is a scalar and h is mu.

tscos.m
- help section format
- help section
  - function is implemented using Definition 3.25
  - write out the definition

tscosh.m
- help section format
- help section
  - function is implemented using Definition 3.17
- write out the definition

tsexp.m
- help section format

tsfind.m
- help section format

tsforward.m
- help section format

tsharmonic.m
- help section format
- included a note explaining that the function generates one more than expected
  - NOTE: Because a harmonic time scale starts at zero, the function returns a harmonic time scale of N+1 points

    i.e. - tsharmonic(10) returns a harmonic timescale with 11 values

tsmu.m
- help section format

tsnu.m
- help section format

tsode.m
- help section format

tspab.m
- help section format

tsplot.m
- help section format

tsqz.m
- help section format

tssin.m
- help section format
- help section
  - function is implemented using Definition 3.25
- write out the definition

tssinh.m
- help section format
- help section
  - function is implemented using Definition 3.17
- write out the definition

tszeros.m
- help section format