GAPoT-gmac MATLAB Toolbox

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Introduction

Geometric Algebra has gained a lot of attention recently. The use of this framework in electrical and power systems has been introduced by the GAPoT theory. However, a powerful and flexible tool is needed in order to manage the large number of dimensions required to deal with systems where harmonics are present. GAPoT-gmac is such a tool. Thanks to its design and architecture it is able to provide the necessary capabilities to perform electrical circuit analysis as well as to evaluate power and energy flows.
This document presents a detailed description of the functions that the GAPoT-gmac library implements in MATLAB, as well as a short guide to its configuration and installation.

The source code is available at Github. The creator is Dr. Ahmad Hosny Eid, Software Engineer and Assistant Professor of Computer Engineering at the Faculty of Engineering, Port-Said University, Egypt. Visit https://ga-explorer.netlify.app for more information.

Download and install

1. Download the latest version of the c++ code GeometricAlgebraNumericsLib from GitHub: https://github.com/ga-explorer/GeometricAlgebraNumericsLib
2. Make sure the GeometricAlgebraNumericsLibSamples project is the default project of the solution
3. Open and Build the GeometricAlgebraNumericsLib solution using x64 Debug configuration
4. In the MATLAB toolbox open the file `gapotInit.m` and edit the variable `gapotAssemblyPath` to be the path containing the `GeometricAlgebraNumericsLib.dll` assembly.
5. In MATLAB add the toolbox folder to the MATLAB path

Library initialization

The library needs to be initialized once MATLAB is ready, so `gapotInit` command should be executed first before operations are performed.

```
>> gapotInit
```

Type definitions and conversion

To operate with vectors and multivectors, it is necessary to define them in a particular way. For example, the definition of vectors can be carried out in several distinct ways (rectangular or polar), so a text parser is needed for an easy and flexible data entry. Once defined, they are stored as objects that can be displayed as text strings or arrays using specific functions.

gapotBivectorToTermsArray.m

%Create a sparse MATLAB array from a GAPoT multivector terms. It is used to convert a multivector object into a readable sparse array. For example, a power multivector M with 6 terms:

```
>> gapotBivectorToTermsArray(M,6)

ans =

   (1,1)            35951.5264416066
   (1,2)            12441.9102309493
   (1,3)           -7248.47355839335
   (1,4)           -12499.6213980426
   (1,5)           -7248.47355839341
   (1,6)            37383.4418599411
```

gapotParseBivector.m

%Parse a GAPoT bivector expression. Creates a multivector object using term components. For example, for the multivector $M = 2 - 5\sigma_{12} + 5\sigma_{34}$

```
>> M = gapotParseBivector("2 <>, -5 <1,2>, 5<3,4>")

M =

  GaPoTNumBivector with no properties
```

gapotParseVector.m

%Parse a GAPoT vector expression. Creates a vector object. Different strategies are possible such as polar or rectangular. For example, for a vector $v = 0.433\sigma_1 - 0.25\sigma_2 + 0.433\sigma_3 + 0.25\sigma_4$

Rectangular

```
>> v = gapotParseVector("r(0.433, -0.25) <1,2>, r(0.433, 0.25) <3,4>")
```

Polar (modulus and angle in radians), with $v = 0.5\mathrm{e}^{0.523\sigma_{12}}\sigma_1 + 0.5\mathrm{e}^{-0.523\sigma_{34}}\sigma_3$

```
>> v = gapotParseVector("p(0.5,0.523598775598299) <1,2>, p(0.5,-0.523598775598299) <3,4>")
```

Rectangular (term by term)

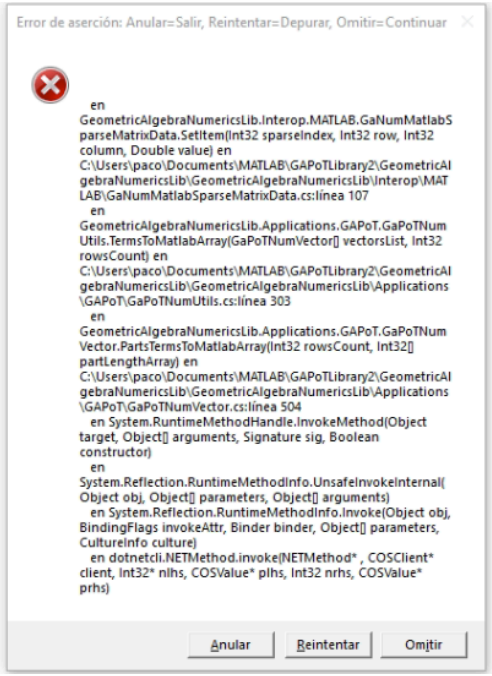
```
>> v = gapotParseVector("0.433 <1>, -0.25 <2>, 0.433 <3>, 0.25 <4>")
```

Note: Remember that GAPoT uses a slightly different criteria for phase angles in Argand diagram. Positive angle in polar form implies a rotation in the CW direction, and negative angles a rotation in CCW direction.

gapotPartsTermsToArray.m

%Create a sparse MATLAB column array from a GAPoT vector's parts

NOT WORKING



gapotPolarPhasorsArrayToVector.m

%Creates a GAPoT vector using MATLAB array of polar phasors. This function allows the creation of a vector using MATLAB variables and operations. One row per harmonic (modulus and phase angle).

```
>> u1 = 5;
>> u2 = 10;

>> mv2 = gapotPolarPhasorsArrayToVector([
    100 * sqrt(2) / u1, 30 * pi / 180;
    200 * sqrt(3) / u2, 60 * pi / 180;
]);
>> gapotDisplayPhasors(mv2)
ans =

p(28.2842712474619, 0.523598775598299) <1,2>, p(34.6410161513775, 1.0471975511966) <3,4>
```

gapotTermsArrayToVector.m

%Creates a GAPoT vector using MATLAB array of rectangular terms. This function allows the creation of a vector using MATLAB variables and operations. One row per harmonic (2 rectangular terms).

```
>> mv1 = gapotTermsArrayToVector([
    100 * sqrt(2) / u1;
    0;
    200 * sqrt(3) / u2 * cos(60 * pi / 180);
    -200 * sqrt(3) / u2 * sin(60 * pi / 180)
]);

>> gapotDisplayTerms(mv1)

ans =

28.2842712474619 <1>, 17.3205080756888 <3>, -30 <4>

>> gapotDisplayPhasors(mv1)
```

```
ans =

p(28.2842712474619, 0) <1,2>, p(34.6410161513775, 1.0471975511966) <3,4>
```

gapotVectorToPolarPhasorsArray.m

%Create a sparse MATLAB array from a GAPoT vector polar phasors. It is used to convert a vector object into a readable sparse array of modulus and phase angle for each harmonic. Using the above vector `mv1`, it reads as

```
>> gapotVectorToPolarPhasorsArray(mv1,3)

ans =

   (1,1)       28.2843
   (2,1)       34.6410
   (2,2)        1.0472
```

gapotVectorToTermsArray.m

%Create a sparse MATLAB array from a GAPoT vector rectangular terms. It is used to convert a vector object into a readable sparse array with rectangular coordinates for each harmonic. Using the above vector `mv1`, it reads as

```
>> gapotVectorToTermsArray(mv1,4)

ans =

   (1,1)       28.2843
   (3,1)       17.3205
   (4,1)      -30.0000
```

Basic operations

A few simple operations have been also implemented to facilitate basic computations.

gapotAdd.m

%Add two GAPoT vectors.

gapotGp.m

%The geometric product of two GAPoT multivectors. When one is a vector and another is a multivector (scalar + bivectors) the result is the vector part of the actual geometric product (the scalar and trivector parts are omitted). Because of GAPoT formulation, the product of a vector and a multivector can only yield a vector, so this operation is optimized for this condition.

```
>> R=gapotGp(mv1,mv2)

R =

  GaPoTNumBivector with no properties.

>> R.TermsToText

ans =

1892.82032302755 <>, -400 <1,2>, 65.6338798447071 <1,3>, -113.681214588903 <1,4>,

244.948974278318 <2,3>, -424.264068711928 <2,4>
```

gapotInverse.m

%Compute the inverse of a GAPoT vector or bivector

```
>> inv=gapotInverse(mv1)

inv =

  GaPoTNumVector with properties:

    Count: 3

>> inv.TermsToText

ans =

0.014142135623731 <1>, 0.00866025403784439 <3>, -0.015 <4>
```

gapotNegative.m

%Compute the negative of a GAPoT vector or bivector

gapotNorm.m

%Compute the norm of a GAPoT vector or bivector

```
>> gapotNorm(mv1)

ans =

   44.7214
```

gapotNorm2.m

%Compute the squared norm of a GAPoT vector or bivector

```
>> gapotNorm2(mv1)

ans =

        2000
```

gapotPower.m

%See gapotGp

gapotReverse.m

%Compute the reverse of a GAPoT vector or bivector

gapotSubtract.m

%Subtract two GAPoT vectors

Human readable format

All vectors and multivectors are stored as objetcs in MATLAB. Some functions needs to be used to display the content in a human readable format.

gapotDisplayPhasors.m

%Display the polar phasors of a GAPoT vector

```
>> gapotDisplayPhasors(mv1)

ans =

p(28.2842712474619, 0) <1,2>, p(34.6410161513775, 1.0471975511966) <3,4>
```

gapotDisplayTerms.m

%Display the terms of a GAPoT vector or bivector

```
>> gapotDisplayTerms(mv1)

ans =

28.2842712474619 <1>, 17.3205080756888 <3>, -30 <4>
```

gapotGetTermPart.m

%Get the term part of a GAPoT power multivector. Mainly used to extract a specific bivector term in the geometric apparent power

```
>> part=gapotGetTermPart(M,3,4)

part =

  GaPoTNumBivector with no properties.

>> part.TermsToText

ans =

5 <3,4>
```

gapotGetTermValue.m

%Get the coefficient of a specific term of a GAPoT power multivector.

```
>> part=gapotGetTermValue(M,3,4)

part =

     5
```

Power related functions

gapotGetActivePart.m

%Get the scalar part of a GAPoT power multivector,i.e., the active Power.

```
>> P=gapotGetActivePart(M)

P =

  GaPoTNumBivector with no properties.

>> P.TermsToText

ans =

2 <>
```

gapotGetActiveTotal.m

%Get the coefficient of the scalar part of a GAPoT power multivector. Actually, is nothing more than P. See gapotGetActivePart.m

gapotGetHarmPart.m

%Get the non-scalar part of a GAPoT power multivector except for <1,2>. Basically, it gets bivector parts related with harmonic distortion and unbalance power.

```
>> H=gapotGetHarmPart(M)

H =

  GaPoTNumBivector with no properties.

>> H.TermsToText

ans =

5 <3,4>
```

gapotGetHarmTotal.m

%Get the non-scalar part values of a GAPoT power multivector except for <1,2>. Sum the coefficients of the extracted terms.

```
>> M = gapotParseBivector("2 <>, -5 <1,2>, 5<3,4>, 7<7,8>")

M =

  GaPoTNumBivector with no properties.

>> H=gapotGetHarmTotal(M)

H = 12
```

gapotGetNonActivePart.m

%Get the non-scalar part of a GAPoT power multivector.

```
>> Non=gapotGetNonActivePart(M)

Non =

  GaPoTNumBivector with no properties.

>> Non.TermsToText

ans =

-5 <1,2>, 5 <3,4>, 7 <7,8>
```

gapotGetNonActiveTotal.m

%Get the non-scalar coefficients of a GAPoT power bivector and sum them.

```
>> gapotGetNonActiveTotal(M)

ans =

     7
```

gapotGetReactiveFundamentalPart.m

%Get the <1,2> non-scalar part of a GAPoT power bivector. According to GAPoT theory, the term <1,2> holds for the fundamental harmonic reactive power.

```
>> Q1=gapotGetReactiveFundamentalPart(M)

Q1 =

  GaPoTNumBivector with no properties.

>> Q1.TermsToText

ans =

-5 <1,2>
```

gapotGetReactiveFundamentalTotal.m

%Get the coefficient of the <1,2> part of a GAPoT power multivector. Actually, is nothing more than Q1. See gapotGetReactiveFundamentalPart.m

gapotGetReactivePart.m

%Get the reactive part of a GAPoT power bivector. It computes the bivector terms in the form <2k-1,2k> where k is the harmonic order.

```
>> Q=gapotGetReactivePart(M)

Q =

  GaPoTNumBivector with no properties.

>> Q.TermsToText

ans =

-5 <1,2>, 5 <3,4>, 7 <7,8>
```

gapotGetReactiveTotal.m

%Sum of the coefficients for terms <2k-1,2k>. It is the reactive power in the Budeanu sense.

```
>> gapotGetReactiveTotal(M)

ans =

     7
```

Others

gapotGetParts.m

%Extract rectangular parts from vectors

```
>> mvuparts=gapotGetParts(mv1,[2,2]);

>> mvuparts(1).TermsToText

ans =

28.2842712474619 <1>
```

```
>> mvuparts(2).TermsToText

ans =

17.3205080756888 <3>, -30 <4>
```

gapotSparseMatrixDataToArray.m

%Function to convert data arrays into a sparse MATLAB array.

Examples

gapotSample1.m

%see code at https://github.com/ga-explorer/GeometricAlgebraNumericsLib/tree/master/GAPoT%20MATLAB%20Toolbox

gapotSample2.m

%see code at https://github.com/ga-explorer/GeometricAlgebraNumericsLib/tree/master/GAPoT%20MATLAB%20Toolbox

gapotSample3.m

%see code at https://github.com/ga-explorer/GeometricAlgebraNumericsLib/tree/master/GAPoT%20MATLAB%20Toolbox

gapotSample4.m

%see code at https://github.com/ga-explorer/GeometricAlgebraNumericsLib/tree/master/GAPoT%20MATLAB%20Toolbox