

AFEPack for Electromagnetic

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# Chapter 1

## Notes on AFEPack for Electromagnetic

In fact, I make it not only for Electromagnetic calculation, but also for the general PDE cases.

In this note, the variational principles for electromagnetic is mainly based on Jian-Ming Jin's the book "The Finite Element Method in Electromagnetics".

### 1.1 Node Finite Elements

Consider the PED in a Lipschitz domain  $\Omega \in \mathcal{R}^d, d = 2, 3$

$$-\nabla \cdot (c(x)\nabla u) + a(x)u = f \quad \in \Omega$$

with right hand side  $f \in L^2(\Omega)^d$ .

The boundary condition is the homogeneous Dirichlet boundary condition

$$u = b \quad \text{on } \partial\Omega_1$$

and the homogeneous Neumann boundary condition

$$\hat{n} \cdot c(x)\nabla u + q(x)u = g \quad \text{on } \partial\Omega_2$$

provided that a,c,q is real or complex and  $\hat{n}$  is the outward normal from S, where  $\partial\Omega_1 + \partial\Omega_2 = \partial\Omega$

#### 1.1.1 Variational Formulation

by applying the first scalar Green's theorem

$$\int_{\Omega} v \nabla \cdot (c \nabla u) + c(\nabla v) \cdot (\nabla u) dV = \oint_{\partial\Omega} cv \frac{\partial u}{\partial n} dS$$

and the boundary conditions above, we can get

$$\int_{\Omega} c(\nabla v) \cdot (\nabla u) dV + \int_{\Omega} a(x)uv dV = \int_{\Omega} fvdV + \oint_{\partial\Omega_2} v(g - q(x)u) dS$$

the forms

$$\begin{aligned} a(u, v) &:= \int_{\Omega} c(\nabla v) \cdot (\nabla u) dV + \int_{\Omega} a(x)uv dV + \oint_{\partial\Omega_2} q(x)vudS \\ rhs(v) &:= \int_{\Omega} fvdV + \oint_{\partial\Omega_2} vgdS \end{aligned}$$

### 1.1.2 Example1

The computational domain is  $[-1, 1] \times [-1, 1]$ . The parameters

$$c(x) = 1, \quad a(x) = 0 \quad \text{and} \quad f = 2\pi^2 \sin(\pi x) \sin(\pi y)$$

the boundary parameters

$$b = 0, q(x) = 0, \quad \text{and} \quad g = \begin{cases} \pi \sin(\pi x) & x \in [-1, 1] \quad \text{and} \quad y = -1 \\ -\pi \sin(\pi y) & x = 1 \quad \text{and} \quad y \in [-1, 1] \\ -\pi \sin(\pi x) & x \in [-1, 1] \quad \text{and} \quad y = 1 \\ \pi \sin(\pi y) & x = -1 \quad \text{and} \quad y \in [-1, 1] \end{cases}$$

The exact solution is

$$u = \sin(\pi x) \sin(\pi y)$$

This figure shows the results of Example.

## 1.2 Vector Finite Elements

consider the vector-valued model problem

$$\nabla \times (c(x) \nabla \times \mathbf{u}) + a(x) \mathbf{u} = \mathbf{f} \quad \in \Omega$$

The boundary conditions are the homogenous Dirichlet boundary condition

$$\hat{n} \times \mathbf{u} = b \quad \text{on } \partial\Omega_1$$

and the homogeneous Neumann boundary condition

$$c(x) \hat{n} \times (\nabla \times \mathbf{u}) + q(x) \hat{n} \times (\hat{n} \times \mathbf{u}) = \mathbf{g} \quad \text{on } \partial\Omega_2$$

with  $\partial\Omega_1 + \partial\Omega_2 = \partial\Omega$ ,  $a, c$ , and  $b, q$  are real(complex) numbers or functions.

### 1.2.1 Variational Formulation

Invoking the first vector Green's theorem and vector identity

$$\begin{aligned} \int_{\Omega} (c \nabla \times \mathbf{v}) \cdot (\nabla \times \mathbf{u}) - \mathbf{v} \cdot (\nabla \times (c \nabla \times \mathbf{u})) dV &= \oint_{\partial\Omega} c (\mathbf{v} \times \nabla \times \mathbf{u}) \cdot \hat{n} dS \\ (\mathbf{v} \times \nabla \times \mathbf{u}) \cdot \hat{n} &= (\hat{n} \times \mathbf{v}) \cdot (\nabla \times \mathbf{u}) = -\mathbf{v} \cdot (\hat{n} \times (\nabla \times \mathbf{u})) \end{aligned}$$

applying the boundary conditions we obtain

$$\int_{\Omega} c (\nabla \times \mathbf{v}) \cdot (\nabla \times \mathbf{u}) dV + \int_{\Omega} a(x) \mathbf{u} \cdot \mathbf{v} dV = \int_{\Omega} \mathbf{f} \cdot \mathbf{v} dV - \oint_{\partial\Omega} \mathbf{v} \cdot (\mathbf{g} - q(x) \hat{n} \times (\hat{n} \times \mathbf{u})) dS$$

the forms

$$\begin{aligned} a(\mathbf{u}, \mathbf{v}) &:= \int_{\Omega} c (\nabla \times \mathbf{v}) \cdot (\nabla \times \mathbf{u}) dV + \int_{\Omega} a(x) \mathbf{u} \cdot \mathbf{v} dV + \oint_{\partial\Omega_2} q(x) (\hat{n} \times \mathbf{u}) \cdot (\hat{n} \times \mathbf{v}) dS \\ rhs(\mathbf{v}) &:= \int_{\Omega} \mathbf{f} \cdot \mathbf{v} dV - \oint_{\partial\Omega} \mathbf{v} \cdot \mathbf{g} dS \end{aligned}$$

### 1.2.2 Example

The computational domain is  $[-1, 1] \times [-1, 1]$ . The parameters

$$c(x) = 1, \quad a(x) = 1 \quad \text{and} \quad f = \begin{pmatrix} (2\pi^2 + 1) \cos(\pi x) \sin(\pi y) \\ -(2\pi^2 + 1) \sin(\pi x) \cos(\pi y) \end{pmatrix}$$

the boundary parameters

$$b = 0, q(x) = 0, \quad \text{and} \quad g = \begin{cases} (-2\pi \cos(\pi x), 0) & x \in [-1, 1] \quad \text{and} \quad y = -1 \\ (0, -2\pi \cos(\pi y)) & x = 1 \quad \text{and} \quad y \in [-1, 1] \\ (2\pi \cos(\pi x), 0) & x \in [-1, 1] \quad \text{and} \quad y = 1 \\ (0, 2\pi \cos(\pi y)) & x = -1 \quad \text{and} \quad y \in [-1, 1] \end{cases}$$

The exact solution is

$$u = \begin{pmatrix} \cos(\pi x) \sin(\pi y) \\ -\sin(\pi x) \cos(\pi y) \end{pmatrix}$$

This figure shows the results of Example



## Chapter 2

# Hierarchical Index

### 2.1 Class Hierarchy

This inheritance list is sorted roughly, but not completely, alphabetically:

GeometryCache< DIM > . . . . .	13
EdgeCache< value_type, DIM > . . . . .	11
EdgeCache< value_type, DIM > . . . . .	11
ElementCache< value_type, DIM > . . . . .	12
ElementCache< value_type, DIM > . . . . .	12
SolutionCache< value_type > . . . . .	14
uiExperiment . . . . .	15





## Chapter 3

# Class Index

### 3.1 Class List

Here are the classes, structs, unions and interfaces with brief descriptions:

<a href="#">EdgeCache&lt; value_type, DIM &gt;</a>	<a href="#">11</a>
<a href="#">ElementCache&lt; value_type, DIM &gt;</a>	<a href="#">12</a>
<a href="#">GeometryCache&lt; DIM &gt;</a>	<a href="#">13</a>
<a href="#">SolutionCache&lt; value_type &gt;</a>	<a href="#">14</a>
<a href="#">uiExperiment</a>	<a href="#">15</a>



## Chapter 4

# File Index

### 4.1 File List

Here is a list of all files with brief descriptions:

<a href="#">mainpage.h</a>	44
complex_edge_THFEM/ <a href="#">D.d</a>	27
complex_edge_THFEM/ <a href="#">datacache.cpp</a>	27
complex_edge_THFEM/ <a href="#">datacache.h</a>	28
complex_edge_THFEM/ <a href="#">emdefs.h</a>	29
complex_edge_THFEM/ <a href="#">main.cpp</a>	34
complex_edge_THFEM/ <a href="#">parameter.h</a>	36
complex_edge_THFEM/ <a href="#">uiexp.cpp</a>	41
complex_edge_THFEM/ <a href="#">uiexp.h</a>	42
complex_node_THFEM/ <a href="#">D.d</a>	27
complex_node_THFEM/ <a href="#">datacache.cpp</a>	28
complex_node_THFEM/ <a href="#">datacache.h</a>	29
complex_node_THFEM/ <a href="#">emdefs.h</a>	32
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complex_node_THFEM/ <a href="#">parameter.h</a>	38
complex_node_THFEM/ <a href="#">uiexp.cpp</a>	41
complex_node_THFEM/ <a href="#">uiexp.h</a>	43



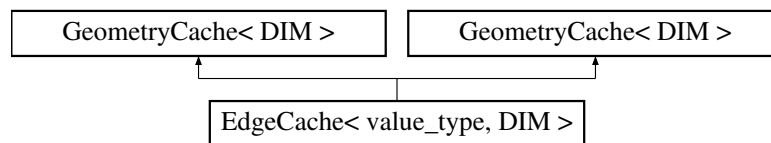
## Chapter 5

# Class Documentation

### 5.1 EdgeCache< value\_type, DIM > Struct Template Reference

```
#include <datacache.h>
```

Inheritance diagram for EdgeCache< value\_type, DIM >:



#### Public Attributes

- `std::vector< std::vector< value_type > >` [basis\\_value](#)
- `std::vector< std::vector< std::vector< value_type > > >` [basis\\_gradient](#)
- `std::vector< std::vector< value_type > >` [un](#)

#### 5.1.1 Member Data Documentation

##### 5.1.1.1 basis\_gradient

```
template<typename value_type , int DIM>
std::vector< std::vector< std::vector< value_type > > > EdgeCache< value_type, DIM >↔
::basis_gradient
```

### 5.1.1.2 basis\_value

```
template<typename value_type , int DIM>
std::vector< std::vector< value_type > > EdgeCache< value_type, DIM >::basis_value
```

### 5.1.1.3 un

```
template<typename value_type , int DIM>
std::vector< std::vector< value_type > > EdgeCache< value_type, DIM >::un
```

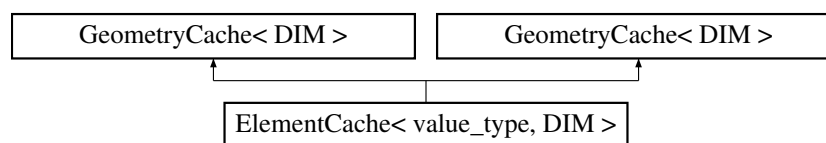
The documentation for this struct was generated from the following file:

- [complex\\_edge\\_THFEM/datacache.h](#)

## 5.2 ElementCache< value\_type, DIM > Struct Template Reference

```
#include <datacache.h>
```

Inheritance diagram for ElementCache< value\_type, DIM >:



### Public Attributes

- double [ind](#)
- std::vector< std::vector< value\_type > > [basis\\_value](#)  
*index of the element*
- std::vector< std::vector< std::vector< value\_type > > > [basis\\_gradient](#)

### 5.2.1 Member Data Documentation

#### 5.2.1.1 basis\_gradient

```
template<typename value_type , int DIM>
std::vector< std::vector< std::vector< value_type > > > ElementCache< value_type, DIM >↔
::basis_gradient
```

## 5.2.1.2 basis\_value

```
template<typename value_type , int DIM>
std::vector< std::vector< value_type > > ElementCache< value_type, DIM >::basis_value
```

index of the element

## 5.2.1.3 ind

```
template<typename value_type , int DIM>
double ElementCache< value_type, DIM >::ind
```

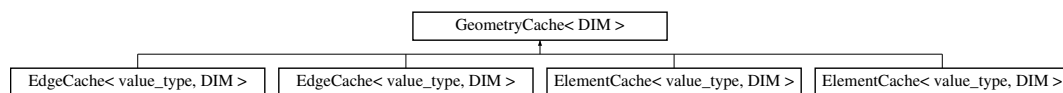
The documentation for this struct was generated from the following file:

- [complex\\_edge\\_THFEM/datacache.h](#)

## 5.3 GeometryCache&lt; DIM &gt; Struct Template Reference

```
#include <datacache.h>
```

Inheritance diagram for GeometryCache< DIM >:



## Public Attributes

- [Point< DIM > bc](#)
- [int n\\_quad\\_pnt](#)
- [std::vector< Point< DIM > > q\\_pnt](#)
- [std::vector< double > Jxw](#)

## 5.3.1 Member Data Documentation

## 5.3.1.1 bc

```
template<int DIM>
Point< DIM > GeometryCache< DIM >::bc
```

### 5.3.1.2 Jxw

```
template<int DIM>
std::vector< double > GeometryCache< DIM >::Jxw
```

### 5.3.1.3 n\_quad\_pnt

```
template<int DIM>
int GeometryCache< DIM >::n_quad_pnt
```

### 5.3.1.4 q\_pnt

```
template<int DIM>
std::vector< Point< DIM > > GeometryCache< DIM >::q_pnt
```

The documentation for this struct was generated from the following file:

- [complex\\_edge\\_THFEM/datacache.h](#)

## 5.4 SolutionCache< value\_type > Struct Template Reference

```
#include <datacache.h>
```

### Public Attributes

- `std::vector< value_type > val`

### 5.4.1 Member Data Documentation

#### 5.4.1.1 val

```
template<class value_type >
std::vector< value_type > SolutionCache< value_type >::val
```

The documentation for this struct was generated from the following file:

- [complex\\_edge\\_THFEM/datacache.h](#)



## 5.5 uiExperiment Class Reference

```
#include <uiexp.h>
```

### Public Member Functions

- [uiExperiment](#) (const std::string &file)  
*time step*
- virtual [~uiExperiment](#) ()
- void [init](#) ()
- void [buildFEMSpace](#) ()
- void [buildDGFEMSpace](#) (int bmark=2)
- void [updateGeometryCache](#) (u\_int alg\_acc=3)
- void [updateDGGeometryCache](#) (u\_int alg\_acc=3)
- void [DirichletBC](#) (CFunc bnd, int bmark=1)
- void [NeummanBC](#) (CvFunc g, int bmark=2)
- void [getRhs](#) ()
- void [getMat](#) ()
- void [solve](#) ()
- void [getError](#) ()
- void [adaptMesh](#) ()
- void [getIndicator](#) ()
- virtual void [saveData](#) ()
- void [run](#) ()
- [uiExperiment](#) (const std::string &file)  
*time step*
- virtual [~uiExperiment](#) ()
- void [init](#) ()
- void [buildFEMSpace](#) ()
- void [buildDGFEMSpace](#) (int bmark=2)
- void [updateGeometryCache](#) (u\_int alg\_acc=3)
- void [updateDGGeometryCache](#) (u\_int alg\_acc=3)
- void [DirichletBC](#) (CFunc bnd, int bmark=1)
- void [NeummanBC](#) (CFunc g, int bmark=2)
- void [getRhs](#) ()
- void [getMat](#) ()
- void [solve](#) ()
- void [getError](#) ()
- void [adaptMesh](#) ()
- void [getIndicator](#) ()
- virtual void [saveData](#) ()
- void [run](#) ()

## Private Attributes

- HGeometryTree< [DIM](#) > [h\\_tree](#)
- IrregularMesh< [DIM](#) > [ir\\_mesh](#)
- std::string [mesh\\_file](#)
- TemplateGeometry< [DIM](#) > [triangle\\_template\\_geometry](#)
- mesh file*
- CoordTransform< [DIM](#), [DIM](#) > [triangle\\_coord\\_transform](#)
- TemplateDOF< [DIM](#) > [triangle\\_template\\_dof](#)
- BasisFunctionAdmin< [vec\\_type](#), [DIM](#), [DIM](#) > [triangle\\_basis\\_function](#)
- UnitOutNormal< [DIM](#) > [triangle\\_unit\\_out\\_normal](#)
- TemplateGeometry< [DIM](#) > [twin\\_triangle\\_template\\_geometry](#)
- CoordTransform< [DIM](#), [DIM](#) > [twin\\_triangle\\_coord\\_transform](#)
- TemplateDOF< [DIM](#) > [twin\\_triangle\\_template\\_dof](#)
- BasisFunctionAdmin< [vec\\_type](#), [DIM](#), [DIM](#) > [twin\\_triangle\\_basis\\_function](#)
- UnitOutNormal< [DIM](#) > [twin\\_triangle\\_unit\\_out\\_normal](#)
- TemplateGeometry< [DIM-1](#) > [interval\\_template\\_geometry](#)
- CoordTransform< [DIM-1](#), [DIM](#) > [interval\\_to2d\\_coord\\_transform](#)
- std::vector< TemplateElement< [vec\\_type](#), [DIM](#), [DIM](#) > > [template\\_element](#)
- std::vector< TemplateDGElement< [DIM-1](#), [DIM](#) > > [dg\\_template\\_element](#)
- DGFEMSpace< [vec\\_type](#), [DIM](#) > [fem\\_space](#)
- std::vector< [ElementCache](#)< [vec\\_type](#), [DIM](#) > > [element\\_cache](#)
- finite element space*
- std::vector< [EdgeCache](#)< double, [DIM](#) > > [edge\\_cache](#)
- FEMFunction< [vec\\_type](#), [DIM](#) > [u\\_re](#)
- FEMFunction< [vec\\_type](#), [DIM](#) > [u\\_im](#)
- Eigen::SparseMatrix< [cvaltype](#), Eigen::RowMajor > [stiff\\_matrix](#)
- Eigen::Matrix< [cvaltype](#), Eigen::Dynamic, 1 > [solution](#)
- Eigen::Matrix< [cvaltype](#), Eigen::Dynamic, 1 > [rhs](#)
- std::vector< [T](#) > [triplets](#)
- Indicator< [DIM](#) > [indicator](#)
- MeshAdaptor< [DIM](#) > [mesh\\_adaptor](#)
- double [sys\\_t0](#) = 0
- double [dt](#) = 1
- system start time*
- BasisFunctionAdmin< double, [DIM](#), [DIM](#) > [triangle\\_basis\\_function](#)
- BasisFunctionAdmin< double, [DIM](#), [DIM](#) > [twin\\_triangle\\_basis\\_function](#)
- std::vector< TemplateElement< double, [DIM](#), [DIM](#) > > [template\\_element](#)
- DGFEMSpace< double, [DIM](#) > [fem\\_space](#)
- std::vector< [ElementCache](#)< double, [DIM](#) > > [element\\_cache](#)
- finite element space*
- FEMFunction< double, [DIM](#) > [u\\_re](#)
- FEMFunction< double, [DIM](#) > [u\\_im](#)

### 5.5.1 Constructor & Destructor Documentation

#### 5.5.1.1 uiExperiment() [1/2]

```
uiExperiment::uiExperiment (
    const std::string & file )
```

time step

#### 5.5.1.2 ~uiExperiment() [1/2]

```
uiExperiment::~~uiExperiment ( ) [virtual]
```

#### 5.5.1.3 uiExperiment() [2/2]

```
uiExperiment::uiExperiment (
    const std::string & file )
```

time step

#### 5.5.1.4 ~uiExperiment() [2/2]

```
virtual uiExperiment::~~uiExperiment ( ) [virtual]
```

### 5.5.2 Member Function Documentation

#### 5.5.2.1 adaptMesh() [1/2]

```
void uiExperiment::adaptMesh ( )
```

#### 5.5.2.2 adaptMesh() [2/2]

```
void uiExperiment::adaptMesh ( )
```

**5.5.2.3 buildDGFEMSpace()** [1/2]

```
void uiExperiment::buildDGFEMSpace (
    int bmark = 2 )
```

**5.5.2.4 buildDGFEMSpace()** [2/2]

```
void uiExperiment::buildDGFEMSpace (
    int bmark = 2 )
```

**5.5.2.5 buildFEMSpace()** [1/2]

```
void uiExperiment::buildFEMSpace ( )
```

**5.5.2.6 buildFEMSpace()** [2/2]

```
void uiExperiment::buildFEMSpace ( )
```

**5.5.2.7 DirichletBC()** [1/2]

```
void uiExperiment::DirichletBC (
    CFunc bnd,
    int bmark = 1 )
```

**5.5.2.8 DirichletBC()** [2/2]

```
void uiExperiment::DirichletBC (
    CFunc bnd,
    int bmark = 1 )
```

**5.5.2.9 getError()** [1/2]

```
void uiExperiment::getError ( )
```

**5.5.2.10** `getError()` [2/2]

```
void uiExperiment::getError ( )
```

**5.5.2.11** `getIndicator()` [1/2]

```
void uiExperiment::getIndicator ( )
```

**5.5.2.12** `getIndicator()` [2/2]

```
void uiExperiment::getIndicator ( )
```

**5.5.2.13** `getMat()` [1/2]

```
void uiExperiment::getMat ( )
```

**5.5.2.14** `getMat()` [2/2]

```
void uiExperiment::getMat ( )
```

**5.5.2.15** `getRhs()` [1/2]

```
void uiExperiment::getRhs ( )
```

**5.5.2.16** `getRhs()` [2/2]

```
void uiExperiment::getRhs ( )
```

**5.5.2.17** `init()` [1/2]

```
void uiExperiment::init ( )
```

**5.5.2.18** `init()` [2/2]

```
void uiExperiment::init ( )
```

**5.5.2.19** `NeummanBC()` [1/2]

```
void uiExperiment::NeummanBC (
    CvFunc g,
    int bmark = 2 )
```

**5.5.2.20** `NeummanBC()` [2/2]

```
void uiExperiment::NeummanBC (
    CFunc g,
    int bmark = 2 )
```

**5.5.2.21** `run()` [1/2]

```
void uiExperiment::run ( )
```

**5.5.2.22** `run()` [2/2]

```
void uiExperiment::run ( )
```

**5.5.2.23** `saveData()` [1/2]

```
void uiExperiment::saveData ( ) [virtual]
```

**5.5.2.24** `saveData()` [2/2]

```
virtual void uiExperiment::saveData ( ) [virtual]
```

**5.5.2.25 solve()** [1/2]

```
void uiExperiment::solve ( )
```

**5.5.2.26 solve()** [2/2]

```
void uiExperiment::solve ( )
```

**5.5.2.27 updateDGGeometryCache()** [1/2]

```
void uiExperiment::updateDGGeometryCache (
    u_int alg_acc = 3 )
```

**5.5.2.28 updateDGGeometryCache()** [2/2]

```
void uiExperiment::updateDGGeometryCache (
    u_int alg_acc = 3 )
```

**5.5.2.29 updateGeometryCache()** [1/2]

```
void uiExperiment::updateGeometryCache (
    u_int alg_acc = 3 )
```

**5.5.2.30 updateGeometryCache()** [2/2]

```
void uiExperiment::updateGeometryCache (
    u_int alg_acc = 3 )
```

**5.5.3 Member Data Documentation****5.5.3.1 dg\_template\_element**

```
std::vector< TemplatedDGElement< DIM-1, DIM > > uiExperiment::dg_template_element [private]
```

### 5.5.3.2 dt

```
double uiExperiment::dt = 1 [private]
```

system start time

### 5.5.3.3 edge\_cache

```
std::vector< EdgeCache< double, DIM > > uiExperiment::edge_cache [private]
```

### 5.5.3.4 element\_cache [1/2]

```
std::vector<ElementCache<double,DIM> > uiExperiment::element_cache [private]
```

finite element space

### 5.5.3.5 element\_cache [2/2]

```
std::vector<ElementCache<vec_type,DIM> > uiExperiment::element_cache [private]
```

finite element space

### 5.5.3.6 fem\_space [1/2]

```
DGFEMSpace<double,DIM> uiExperiment::fem_space [private]
```

### 5.5.3.7 fem\_space [2/2]

```
DGFEMSpace<vec_type,DIM> uiExperiment::fem_space [private]
```

### 5.5.3.8 h\_tree

```
HGeometryTree< DIM > uiExperiment::h_tree [private]
```



#### 5.5.3.9 indicator

```
Indicator< DIM > uiExperiment::indicator [private]
```

#### 5.5.3.10 interval\_template\_geometry

```
TemplateGeometry< DIM-1 > uiExperiment::interval_template_geometry [private]
```

#### 5.5.3.11 interval\_to2d\_coord\_transform

```
CoordTransform< DIM-1, DIM > uiExperiment::interval_to2d_coord_transform [private]
```

#### 5.5.3.12 ir\_mesh

```
IrregularMesh< DIM > uiExperiment::ir_mesh [private]
```

#### 5.5.3.13 mesh\_adaptor

```
MeshAdaptor< DIM > uiExperiment::mesh_adaptor [private]
```

#### 5.5.3.14 mesh\_file

```
std::string uiExperiment::mesh_file [private]
```

#### 5.5.3.15 rhs

```
Eigen::Matrix< cvaltype, Eigen::Dynamic, 1 > uiExperiment::rhs [private]
```

#### 5.5.3.16 solution

```
Eigen::Matrix< cvaltype, Eigen::Dynamic, 1 > uiExperiment::solution [private]
```

#### 5.5.3.17 stiff\_matrix

```
Eigen::SparseMatrix< cvaltype, Eigen::RowMajor > uiExperiment::stiff_matrix [private]
```

#### 5.5.3.18 sys\_t0

```
double uiExperiment::sys_t0 = 0 [private]
```

#### 5.5.3.19 template\_element [1/2]

```
std::vector<TemplateElement<double,DIM,DIM> > uiExperiment::template_element [private]
```

#### 5.5.3.20 template\_element [2/2]

```
std::vector<TemplateElement<vec_type,DIM,DIM> > uiExperiment::template_element [private]
```

#### 5.5.3.21 triangle\_basis\_function [1/2]

```
BasisFunctionAdmin<double,DIM,DIM> uiExperiment::triangle_basis_function [private]
```

#### 5.5.3.22 triangle\_basis\_function [2/2]

```
BasisFunctionAdmin<vec_type,DIM,DIM> uiExperiment::triangle_basis_function [private]
```

#### 5.5.3.23 triangle\_coord\_transform

```
CoordTransform< DIM, DIM > uiExperiment::triangle_coord_transform [private]
```

#### 5.5.3.24 triangle\_template\_dof

```
TemplateDOF< DIM > uiExperiment::triangle_template_dof [private]
```

#### 5.5.3.25 triangle\_template\_geometry

TemplateGeometry< DIM > uiExperiment::triangle\_template\_geometry [private]

mesh file

#### 5.5.3.26 triangle\_unit\_out\_normal

UnitOutNormal< DIM > uiExperiment::triangle\_unit\_out\_normal [private]

#### 5.5.3.27 triplets

std::vector< T > uiExperiment::triplets [private]

#### 5.5.3.28 twin\_triangle\_basis\_function [1/2]

BasisFunctionAdmin<double,DIM,DIM> uiExperiment::twin\_triangle\_basis\_function [private]

#### 5.5.3.29 twin\_triangle\_basis\_function [2/2]

BasisFunctionAdmin<vec\_type,DIM,DIM> uiExperiment::twin\_triangle\_basis\_function [private]

#### 5.5.3.30 twin\_triangle\_coord\_transform

CoordTransform< DIM, DIM > uiExperiment::twin\_triangle\_coord\_transform [private]

#### 5.5.3.31 twin\_triangle\_template\_dof

TemplateDOF< DIM > uiExperiment::twin\_triangle\_template\_dof [private]

#### 5.5.3.32 twin\_triangle\_template\_geometry

TemplateGeometry< [DIM](#) > uiExperiment::twin\_triangle\_template\_geometry [private]

#### 5.5.3.33 twin\_triangle\_unit\_out\_normal

UnitOutNormal< [DIM](#) > uiExperiment::twin\_triangle\_unit\_out\_normal [private]

#### 5.5.3.34 u\_im [1/2]

FEMFunction<double,[DIM](#)> uiExperiment::u\_im [private]

#### 5.5.3.35 u\_im [2/2]

FEMFunction<[vec\\_type](#),[DIM](#)> uiExperiment::u\_im [private]

#### 5.5.3.36 u\_re [1/2]

FEMFunction<double,[DIM](#)> uiExperiment::u\_re [private]

#### 5.5.3.37 u\_re [2/2]

FEMFunction<[vec\\_type](#),[DIM](#)> uiExperiment::u\_re [private]

The documentation for this class was generated from the following files:

- [complex\\_edge\\_THFEM/uiexp.h](#)
- [complex\\_edge\\_THFEM/datacache.cpp](#)
- [complex\\_edge\\_THFEM/uiexp.cpp](#)

## Chapter 6

# File Documentation

### 6.1 complex\_edge\_THFEM/D.d File Reference

### 6.2 complex\_node\_THFEM/D.d File Reference

### 6.3 complex\_edge\_THFEM/datacache.cpp File Reference

```
#include "uiexp.h"
#include "datacache.h"
```

#### Functions

- `template<class value_type , int DIM, int DOW = DIM, int TDIM = DIM>`  
`void updateElementGeometryInfo (Element< value_type, DIM > &ele, u_int alg_acc, ElementCache<`  
`value_type, DIM > &ec)`

#### 6.3.1 Function Documentation

##### 6.3.1.1 updateElementGeometryInfo()

```
template<class value_type , int DIM, int DOW = DIM, int TDIM = DIM>
void updateElementGeometryInfo (
    Element< value_type, DIM > & ele,
    u_int alg_acc,
    ElementCache< value_type, DIM > & ec )
```

## 6.4 complex\_node\_THFEM/datacache.cpp File Reference

```
#include "uiexp.h"
#include "datacache.h"
```

### Functions

- template<class value\_type , int DIM, int DOW = DIM, int TDIM = DIM>  
void [updateElementGeometryInfo](#) (Element< value\_type, DIM > &ele, u\_int alg\_acc, [ElementCache](#)< value\_type, DIM > &ec)
- template<class value\_type , int DIM, int DOW = DIM, int TDIM = DIM>  
void [updateEdgeGeometryInfo](#) (DGElement< value\_type, DIM > &edge, u\_int alg\_acc, [EdgeCache](#)< value\_type, DIM > &ec)

### 6.4.1 Function Documentation

#### 6.4.1.1 [updateEdgeGeometryInfo\(\)](#)

```
template<class value_type , int DIM, int DOW = DIM, int TDIM = DIM>
void updateEdgeGeometryInfo (
    DGElement< value_type, DIM > & edge,
    u_int alg_acc,
    EdgeCache< value_type, DIM > & ec )
```

#### 6.4.1.2 [updateElementGeometryInfo\(\)](#)

```
template<class value_type , int DIM, int DOW = DIM, int TDIM = DIM>
void updateElementGeometryInfo (
    Element< value_type, DIM > & ele,
    u_int alg_acc,
    ElementCache< value_type, DIM > & ec )
```

## 6.5 complex\_edge\_THFEM/datacache.h File Reference

```
#include <lac/full_matrix.h>
```

### Classes

- struct [SolutionCache](#)< value\_type >
- struct [GeometryCache](#)< DIM >
- struct [EdgeCache](#)< value\_type, DIM >
- struct [ElementCache](#)< value\_type, DIM >

## 6.6 complex\_node\_THFEM/datacache.h File Reference

```
#include <lac/full_matrix.h>
```

### Classes

- struct [SolutionCache](#)< value\_type >
- struct [GeometryCache](#)< DIM >
- struct [EdgeCache](#)< value\_type, DIM >
- struct [ElementCache](#)< value\_type, DIM >

## 6.7 complex\_edge\_THFEM/emdefs.h File Reference

```
#include <cmath>
#include <complex>
```

### Macros

- `#define PI (4.0*atan(1.0))`  
*vacuum magnetic permeability*

### Typedefs

- typedef double [valtype](#)
- typedef std::complex< [valtype](#) > [cvaltype](#)
- typedef nVector< [vector\\_length](#), double > [vec\\_type](#)
- typedef nVector< [vector\\_length](#), [cvaltype](#) > [cvec\\_type](#)  
*vector\_value type*
- typedef [valtype](#) [emtype](#)
- typedef [valtype](#)(\* [Func](#)) (const double \*)
- typedef [cvaltype](#)(\* [CFunc](#)) (const double \*)
- typedef [vec\\_type](#)(\* [vFunc](#)) (const double \*)
- typedef [cvec\\_type](#)(\* [CvFunc](#)) (const double \*)

### Functions

- const [cvaltype](#) [I](#) (0, 1)

### Variables

- const double [C](#) =300
- const double [eps0](#) =1./[C](#)  
*speed of light ,nm/fs*
- const double [mue0](#) =1./[C](#)  
*vacuum electrical permittivity*

## 6.7.1 Macro Definition Documentation

### 6.7.1.1 PI

```
#define PI (4.0*atan(1.0))
```

vacuum magnetic permeability

## 6.7.2 Typedef Documentation

### 6.7.2.1 CFunc

```
typedef cvaltype(* CFunc) (const double *)
```

### 6.7.2.2 cvaltype

```
typedef std::complex<valtype> cvaltype
```

### 6.7.2.3 cvec\_type

```
typedef nVector<vector\_length,cvaltype> cvec\_type
```

vector\_value type

### 6.7.2.4 CvFunc

```
typedef cvec\_type(* CvFunc) (const double *)
```

### 6.7.2.5 emtype

```
typedef valtype emtype
```



#### 6.7.2.6 Func

```
typedef valtype(* Func) (const double *)
```

#### 6.7.2.7 valtype

```
typedef double valtype
```

#### 6.7.2.8 vec\_type

```
typedef nVector<vector_length,double> vec_type
```

#### 6.7.2.9 vFunc

```
typedef vec_type(* vFunc) (const double *)
```

### 6.7.3 Function Documentation

#### 6.7.3.1 I()

```
const cvaltype I (  
    0 ,  
    1 )
```

### 6.7.4 Variable Documentation

#### 6.7.4.1 C

```
const double C =300
```

#### 6.7.4.2 eps0

```
const double eps0 =1./C
```

speed of light ,nm/fs

#### 6.7.4.3 mue0

```
const double mue0 =1./C
```

vacuum electrical permittivity

## 6.8 complex\_node\_THFEM/emdefs.h File Reference

```
#include <cmath>
#include <complex>
```

### Macros

- `#define PI (4.0*atan(1.0))`  
*vacuum magnetic permeability*

### Typedefs

- `typedef double valtype`
- `typedef std::complex< valtype > cvaltype`
- `typedef valtype emtype`
- `typedef double(* Func) (const double *)`
- `typedef cvaltype(* CFunc) (const double *)`

### Functions

- `const cvaltype I (0, 1)`

### Variables

- `const double C =300`
- `const double eps0 =1./C`  
*speed of light ,nm/fs*
- `const double mue0 =1./C`  
*vacuum electrical permittivity*

## 6.8.1 Macro Definition Documentation

### 6.8.1.1 PI

```
#define PI (4.0*atan(1.0))
```

vacuum magnetic permeability

## 6.8.2 Typedef Documentation

### 6.8.2.1 CFunc

```
typedef cvaltype(* CFunc) (const double *)
```

### 6.8.2.2 cvaltype

```
typedef std::complex<valtype> cvaltype
```

### 6.8.2.3 emtype

```
typedef valtype emtype
```

### 6.8.2.4 Func

```
typedef double(* Func) (const double *)
```

### 6.8.2.5 valtype

```
typedef double valtype
```

### 6.8.3 Function Documentation

#### 6.8.3.1 I()

```
const cvaltype I (  
    0 ,  
    1 )
```

### 6.8.4 Variable Documentation

#### 6.8.4.1 C

```
const double C =300
```

#### 6.8.4.2 eps0

```
const double eps0 =1./C
```

speed of light ,nm/fs

#### 6.8.4.3 mue0

```
const double mue0 =1./C
```

vacuum electrical permittivity

## 6.9 complex\_edge\_THFEM/main.cpp File Reference

```
#include "uiexp.h"
```

### Macros

- #define EMUNITS

## Functions

- int [main](#) (int argc, char \*argv[])

### 6.9.1 Macro Definition Documentation

#### 6.9.1.1 EMUNITS

```
#define EMUNITS
```

### 6.9.2 Function Documentation

#### 6.9.2.1 main()

```
int main (  
    int argc,  
    char * argv[] )
```

## 6.10 complex\_node\_THFEM/main.cpp File Reference

```
#include "uiexp.h"
```

## Macros

- #define [EMUNITS](#)

## Functions

- int [main](#) (int argc, char \*argv[])

### 6.10.1 Macro Definition Documentation

#### 6.10.1.1 EMUNITS

```
#define EMUNITS
```

## 6.10.2 Function Documentation

### 6.10.2.1 main()

```
int main (
    int argc,
    char * argv[] )
```

## 6.11 complex\_edge\_THFEM/parameter.h File Reference

```
#include "emdefs.h"
```

### Functions

- const [vec\\_type](#) [val\\_0](#) (0)
- [cvec\\_type](#) [u\\_exact](#) (const double \*p)
- [cvaltype](#) [a](#) (const double \*p)
- [cvaltype](#) [c](#) (const double \*p)
- [cvec\\_type](#) [f](#) (const double \*p)
- [cvaltype](#) [q](#) (const double \*p)
- [cvec\\_type](#) [g1](#) (const double \*p)
- [cvec\\_type](#) [g2](#) (const double \*p)
- [cvec\\_type](#) [g3](#) (const double \*p)
- [cvec\\_type](#) [g4](#) (const double \*p)
- [cvaltype](#) [bnd](#) (const double \*p)

### Variables

- double [lambda](#) = 10.
- double [freq](#) = [C](#)/[lambda](#)
- double [k0](#) = 2\*[PI](#)\*[lambda](#)

## 6.11.1 Function Documentation

### 6.11.1.1 a()

```
cvaltype a (
    const double * p )
```

#### 6.11.1.2 bnd()

```
cvaltype bnd (  
    const double * p )
```

#### 6.11.1.3 c()

```
cvaltype c (  
    const double * p )
```

#### 6.11.1.4 f()

```
cvec_type f (  
    const double * p )
```

#### 6.11.1.5 g1()

```
cvec_type g1 (  
    const double * p )
```

#### 6.11.1.6 g2()

```
cvec_type g2 (  
    const double * p )
```

#### 6.11.1.7 g3()

```
cvec_type g3 (  
    const double * p )
```

#### 6.11.1.8 g4()

```
cvec_type g4 (  
    const double * p )
```

#### 6.11.1.9 q()

```
cvaltype q (
    const double * p )
```

#### 6.11.1.10 u\_exact()

```
cvec_type u_exact (
    const double * p )
```

#### 6.11.1.11 val\_0()

```
const vec_type val_0 (
    0 )
```

### 6.11.2 Variable Documentation

#### 6.11.2.1 freq

```
double freq = C/lambda
```

#### 6.11.2.2 k0

```
double k0 = 2*PI*lambda
```

#### 6.11.2.3 lambda

```
double lambda = 10.
```

## 6.12 complex\_node\_THFEM/parameter.h File Reference

```
#include "emdefs.h"
```



## Functions

- `cvaltype u_exact` (const double \*p)
- `cvaltype a` (const double \*p)
- `cvaltype c` (const double \*p)
- `cvaltype f` (const double \*p)
- `cvaltype q` (const double \*p)
- `cvaltype g1` (const double \*p)
- `cvaltype g2` (const double \*p)
- `cvaltype g3` (const double \*p)
- `cvaltype g4` (const double \*p)
- `cvaltype bnd` (const double \*p)

## Variables

- double `lambda` = 10.
- double `freq` = `C/lambda`
- double `k0` = `2*PI*lambda`

### 6.12.1 Function Documentation

#### 6.12.1.1 `a()`

```
cvaltype a (  
    const double * p )
```

#### 6.12.1.2 `bnd()`

```
cvaltype bnd (  
    const double * p )
```

#### 6.12.1.3 `c()`

```
cvaltype c (  
    const double * p )
```

#### 6.12.1.4 `f()`

```
cvaltype f (  
    const double * p )
```

#### 6.12.1.5 g1()

```
cvaltype g1 (  
    const double * p )
```

#### 6.12.1.6 g2()

```
cvaltype g2 (  
    const double * p )
```

#### 6.12.1.7 g3()

```
cvaltype g3 (  
    const double * p )
```

#### 6.12.1.8 g4()

```
cvaltype g4 (  
    const double * p )
```

#### 6.12.1.9 q()

```
cvaltype q (  
    const double * p )
```

#### 6.12.1.10 u\_exact()

```
cvaltype u_exact (  
    const double * p )
```

### 6.12.2 Variable Documentation

#### 6.12.2.1 freq

```
double freq = C/lambda
```

#### 6.12.2.2 k0

```
double k0 = 2*PI*lambda
```

#### 6.12.2.3 lambda

```
double lambda = 10.
```

### 6.13 complex\_edge\_THFEM/uiexp.cpp File Reference

```
#include "uiexp.h"  
#include "parameter.h"
```

### 6.14 complex\_node\_THFEM/uiexp.cpp File Reference

```
#include "uiexp.h"  
#include "parameter.h"
```

#### Functions

- void [writeMatlabData](#) (const std::string &filename, FEMFunction< double, [DIM](#) > u\_h)

#### 6.14.1 Function Documentation

##### 6.14.1.1 writeMatlabData()

```
void writeMatlabData (  
    const std::string & filename,  
    FEMFunction< double, DIM > u_h )
```

## 6.15 complex\_edge\_THFEM/uiexp.h File Reference

```
#include <AFEPack/HGeometry.h>
#include <AFEPack/Geometry.h>
#include <AFEPack/TemplateElement.h>
#include <AFEPack/FEMSpace.h>
#include <AFEPack/DGFEMSpace.h>
#include <AFEPack/Operator.h>
#include <AFEPack/Functional.h>
#include <AFEPack/EasyMesh.h>
#include <AFEPack/MovingMesh2D.h>
#include <Eigen/Sparse>
#include <string>
#include <iostream>
#include <cstdlib>
#include <sstream>
#include <cmath>
#include "emdefs.h"
#include "datacache.h"
```

### Classes

- class [uiExperiment](#)

### Typedefs

- typedef Eigen::Triplet< [cvaltype](#) > [T](#)

### Variables

- const int [DIM](#) = 2
- const int [DOW](#) = [DIM](#)
- const int [TDIM](#) = [DIM](#)
- const int [vector\\_length](#) = [DIM](#)

### 6.15.1 Typedef Documentation

#### 6.15.1.1 T

```
typedef Eigen::Triplet<cvaltype> T
```

### 6.15.2 Variable Documentation

### 6.15.2.1 DIM

```
const int DIM = 2
```

### 6.15.2.2 DOW

```
const int DOW = DIM
```

### 6.15.2.3 TDIM

```
const int TDIM = DIM
```

### 6.15.2.4 vector\_length

```
const int vector_length = DIM
```

## 6.16 complex\_node\_THFEM/uiexp.h File Reference

```
#include <AFEPack/HGeometry.h>
#include <AFEPack/Geometry.h>
#include <AFEPack/TemplateElement.h>
#include <AFEPack/FEMSpace.h>
#include <AFEPack/DGFEMSpace.h>
#include <AFEPack/Operator.h>
#include <AFEPack/Functional.h>
#include <AFEPack/EasyMesh.h>
#include <AFEPack/MovingMesh2D.h>
#include <Eigen/Sparse>
#include <string>
#include <iostream>
#include <cstdlib>
#include <sstream>
#include <cmath>
#include "emdefs.h"
#include "datacache.h"
```

### Classes

- class [uiExperiment](#)

## Typedefs

- `typedef Eigen::Triplet< cvaltype > T`

## Variables

- `const int DIM = 2`
- `const int DOW = DIM`
- `const int TDIM = DIM`

### 6.16.1 Typedef Documentation

#### 6.16.1.1 [T](#)

```
typedef Eigen::Triplet<cvaltype> T
```

### 6.16.2 Variable Documentation

#### 6.16.2.1 [DIM](#)

```
const int DIM = 2
```

#### 6.16.2.2 [DOW](#)

```
const int DOW = DIM
```

#### 6.16.2.3 [TDIM](#)

```
const int TDIM = DIM
```

## 6.17 [mainpage.h](#) File Reference

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