

[Help](#)

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/*
 * Written by David Pommier <david.pommier@gmail.com>
 * INRIA 2009
 */

#include <stdlib.h>
#include <stdio.h>
#include <string.h>
#include "pnl/pnl_random.h"
#include "pnl/pnl_vector.h"
#include "pnl/pnl_linalgsolver.h"
#include "pnl/pnl_finance.h"
#include "pde_tools.h"
#include "gridsparse_functions.h"
#include "gridsparse_constructor.h"

#define SPARSE_N2H(Vout,Vin,index,father) LET(Vout,index)=GET(Vin,index)-0.5*(
#define SPARSE_H2N(Vout,Vin,index,father) LET(Vout,index)=GET(Vin,index)+0.5*(
#define SPARSE_N2H_FUNC(Vin,index,father) GET(Vin,index)-0.5*( GET(Vin,(*father

int log2int(int x)
{
    int level, y;
    if (x == 0)
    {
        printf("error in log2int ");
        abort();
    }
    level = 0;
    y = x;
    while (y > 1)
    {
        level++;
        y >>= 1;
    }
    return level;
}
```

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static double dyadic_cast(int i)
{
    /* \ frac{2 (i-2^{lev}))+1 }{2^{lev+1}} */
    int l = log2int(i);
    return (double)((((i - (1 << l)) << 1) + 1) /
        (double)(2 << l);
}

static void vect_int_dyadic_cast(const PnlVectInt *v_in, PnlVect *v_out)
{
    int i;
    for (i = 0; i < v_in->size; i++)
        LET(v_out, i) = dyadic_cast(v_in->array[i]);
}

double GridSparse_real_value_at_points(GridSparse *G, int d, int i)
{
    return premia_pde_boundary_real_variable(G->Bnd->array[d],
        dyadic_cast(pnl_mat_int_get(G->Points, i, d)));
}

/*static double Nodal_to_Hier_in_point(const int i,const int Dir,
    const PnlVect * V,
    const GridSparse * G)
{
    int PP[3]={Dir,i,0};
    int * father = pnl_hmat_int_lget(G->Ind_Father,PP);
    return GET(V,i)-0.5*( GET(V,(*father))+GET(V,(++father)));
};*/

/**
 * Compute hierarchical coefficients from nodal coefficients
 * in one direction
 *
 * @param Dir a int, the direction,
 * @param V a PnlVect pointer on nodal coefficients,
 * @param Vout a PnlVect pointer on hierarchic coefficients,

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    * @param G a GridSparse pointer
    */
void Nodal_to_Hier_in_dir(const int Dir, const PnlVect *V,
                        PnlVect *Vout, const GridSparse *G)
{
    if (Dir > G->dim)
    {
        printf("error in dimension");
        abort();
    }
    else
    {
        int i = 1;
        int PP[3] = {Dir, 1, 0};
        int *father = pnl_hmat_int_lget(G->Ind_Father, PP);
        do
        {
            LET(Vout, i) = GET(V, i) - 0.5 * (GET(V, (*father)) + GET(V, *(father
            i++;
            father += 2;
        }
        while (i < G->size);
    }
};

/**
 * Compute nodal coefficients from hierarchical coefficients
 * in one direction
 *
 * @param Dir a int, the direction,
 * @param V a PnlVect pointer on hierarchic coefficients,
 * @param Vout a PnlVect pointer on nodal coefficients,
 * @param G a GridSparse pointer
 */
void Hier_to_Nodal_in_dir(int Dir, const PnlVect *V, PnlVect *Vout, const Gri
{
    if (Dir > G->dim)
    {
        printf("error in dimension");
    }

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        abort();
    }
    else
    {
        int i = 1;
        int PP[3] = {Dir, i, 0};
        int *father = pnl_hmat_int_lget(G->Ind_Father, PP);
        do
        {
            LET(Vout, i) = GET(V, i) + 0.5 * (GET(Vout, (*father)) + GET(Vout, *(f
            i++;
            father += 2;
        }
        while (i < G->size);
    }
}

```

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/**
 * Compute hierarchical coefficients from nodal coefficients
 *
 * @param V a PnlVect pointer of nodalcoefficients
 * which becomes hierarchic coefficients,
 * @param G a GridSparse pointer
 */
void Nodal_to_Hier(PnlVect *V, const GridSparse *G)
{
    int i;
    PnlVect *V_Tmp = pnl_vect_copy(V);
    if (G->dim % 2 == 0)
        for (i = 0; i < G->dim; i++)
        {
            Nodal_to_Hier_in_dir(i, V, V_Tmp, G);
            i++;
            Nodal_to_Hier_in_dir(i, V_Tmp, V, G);
        }
    else
    {
        for (i = 0; i < G->dim - 1; i++)
        {
            Nodal_to_Hier_in_dir(i, V_Tmp, V, G);

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        i++;
        Nodal_to_Hier_in_dir(i, V, V_Tmp, G);
    }
    Nodal_to_Hier_in_dir(G->dim - 1, V_Tmp, V, G);
}
pnl_vect_free(&V_Tmp);
}

/**
 * Compute nodal coefficients from hierarchical coefficients
 *
 * @param V a PnlVect pointer of hierarchic coefficients
 * which becomes nodal coefficients,
 * @param G a GridSparse pointer
 */
/*
void Hier_to_Nodal(PnlVect* V, const GridSparse *G)
{
    PnlVect * V_Tmp= pnl_vect_copy(V);
    int i;
    if(G->dim % 2 == 0)
        for(i=G->dim-1; i>0; i--)
        {
            Hier_to_Nodal_in_dir(i, V, V_Tmp, G);
            i--;
            Hier_to_Nodal_in_dir(i, V_Tmp, V, G);
        }
    else
    {
        for(i=G->dim-1; i>1; i--)
        {
            Hier_to_Nodal_in_dir(i, V_Tmp, V, G);
            i--;
            Hier_to_Nodal_in_dir(i, V, V_Tmp, G);
        }
        Hier_to_Nodal_in_dir(0, V_Tmp, V, G);
    }
    pnl_vect_free(&V_Tmp);
};
*/
void Hier_to_Nodal(PnlVect *V, const GridSparse *G)

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```

{
    int i;
    PnlVect *V_Tmp = pnl_vect_copy(V);
    if (G->dim % 2 == 0)
        for (i = 0; i < G->dim - 1; i++)
        {
            Hier_to_Nodal_in_dir(i, V, V_Tmp, G);
            i++;
            Hier_to_Nodal_in_dir(i, V_Tmp, V, G);
        }
    else
    {
        for (i = 0; i < G->dim - 1; i++)
        {
            Hier_to_Nodal_in_dir(i, V_Tmp, V, G);
            i++;
            Hier_to_Nodal_in_dir(i, V, V_Tmp, G);
        }
        Hier_to_Nodal_in_dir(G->dim - 1, V_Tmp, V, G);
    }
    pnl_vect_free(&V_Tmp);
}

/**
 * Compute nodal coefficients from hierarchical coefficients
 *
 * @param Vin a PnlVect pointer of hierarchic coefficients
 * @param G a GridSparse pointer
 * @return a PnlVect pointer with nodal coefficients,
 */
PnlVect *V_Hier_to_Nodal(const PnlVect *Vin,
                        const GridSparse *G)
{
    PnlVect *VTmp = pnl_vect_copy(Vin);
    Hier_to_Nodal(VTmp, G);
    return VTmp;
}

/**
 * Compute distance between two points in dyadic representation
 *

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* @param a a Int
* @param b a Int
* @return abs(abcisse(a)-abcisse(b))
*/
static int Step(int a, int b)
{
    return (a < b) ? log2int(b) + 1 : log2int(a) + 1;
}

/**
* A Get function,
*
* @param G a GridSparse pointer
* @param dir a int, the direction,
* @return size of domaine in direction dir.
*/
static double Domain_Size(const GridSparse *G, int dir)
{
    return G->Bnd->array[dir].H;
}

/**
* WARNING:Assumption homogen Grid,
* Compute the second finite difference operator in direction dir, on point i
*
* @param i a int, index of point on which we compute finite differencial operator
* @param dir a int, direction in which we compute finite differencial operator
* @param v a PnlVect pointer of nodal coefficients in direction dir
* and hierarchic coefficients in others directions
* @param G a GridSparse pointer
* @param l_Ind_neig an int, index of left neighbour
* @param r_Ind_neig an int, index of right neighbour
* @return a double equal to the discret finite difference operator
*/
double FD_Lap_Stencil_Center(const int i, const int dir,
                             const PnlVect *v,
                             GridSparse *G,
                             int l_Ind_neig,
                             int r_Ind_neig)
{
    double Res = GET(v, (l_Ind_neig)) - 2.*GET(v, i) + GET(v, r_Ind_neig);

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Res *= pow(Domain_Size(G, dir), 2)
      * (double)(1 << (2 * (Step(pnl_mat_int_get(G->Points, i, dir),
                                pnl_mat_int_get(G->Points, l_Ind_neig, dir))
/* if ((l_Ind_neig==0)||(r_Ind_neig==0))
{
  Res =GET(v,(l_Ind_neig))-2*GET(v,i)+GET(v,r_Ind_neig);
  Res*=pow(Domain_Size(G,dir),2)
  *(double)(1<<(2*(Step(pnl_mat_int_get(G->Points,i,dir),
                        pnl_mat_int_get(G->Points,l_Ind_neig,dir)))));
  printf(" point %d, index %d steps %d val %7.4f, val %7.4f --> Value %7.4f\n",
        Step(pnl_mat_int_get(G->Points,i,dir),
        pnl_mat_int_get(G->Points,l_Ind_neig,dir)),
        GET(v,l_Ind_neig),+GET(v,r_Ind_neig),Res);

  }*/
return Res;
}

/**
 * WARNING:Assumption homogen Grid,
 * Compute the first order finite difference operator with centered scheme
 * in direction dir, on point i
 *
 * @param i a int, index of point on which we compute finite differencial operator
 * @param dir a int, direction in which we compute finite differencial operator
 * @param v a PnlVect pointer of nodal coefficients in direction dir
 * and hierarchic coefficients in others directions
 * @param G a GridSparse pointer
 * @param l_Ind_neig an int, index of left neighbour
 * @param r_Ind_neig an int, index of right neighbour
 * @return a double equal to the discret finite difference operator
 */
double FD_Conv_Stencil_Center(const int i, const int dir,
                              const PnlVect *v,
                              const GridSparse *G,
                              int l_Ind_neig,
                              int r_Ind_neig)
{
  double res = GET(v, r_Ind_neig) - GET(v, l_Ind_neig);
  res *= Domain_Size(G, dir) *
        (double)(1 << (Step(pnl_mat_int_get(G->Points, i, dir),

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        pnl_mat_int_get(G->Points, l_Ind_neig, dir)) - 1));
    return res;
}

/**
 * WARNING:Assumption homogen Grid,
 * Compute the first order finite difference operator with centered scheme in di
 *
 * @param i a int, index of point on which we compute finite differencial operat
 * @param dir a int, direction in which we compute finite differencial operator
 * @param v a PnlVect pointer of nodal coefficients in direction dir
 * and hierarchic coefficients in others directions
 * @param G a GridSparse pointer
 * @param Ind_neig an int, index of left neighbour
 * @return a double equal to the discret finite difference operator
 */
double FD_Conv_Stencil_DeCenter(const int i, const int dir,
                                const PnlVect *v,
                                const GridSparse *G,
                                int Ind_neig)
{
    double res = GET(v, i) - GET(v, Ind_neig);
    res *= Domain_Size(G, dir) *
        (double)(1 << (Step(pnl_mat_int_get(G->Points, i, dir),
                                pnl_mat_int_get(G->Points, Ind_neig, dir))));
    return res;
}

/**
 * WARNING:Assumption homogen Grid,
 * Compute the second finite difference operator in direction dir, on point i
 *
 * @param i a int, index of point on which we compute finite differencial operat
 * @param dir a int, direction in which we compute finite differencial operator
 * @param v a PnlVect pointer of nodal coefficients in direction dir
 * and hierarchic coefficients in others directions
 * @param G a GridSparse pointer
 * @return a double equal to the discret finite difference operator
 */
/*Assumption homogen Grid */

```

```

double FD_Lap_Center(const int i, const int dir,
                    const PnlVect *v,
                    GridSparse *G)
{
    int PP[3] = {dir, i, 0};
    int *Ind_neig = Ind_neig = pnl_hmat_int_lget(G->Ind_Neigh, PP);
    return FD_Lap_Stencil_Center(i, dir, v, G, *Ind_neig, *(Ind_neig + 1));
}

/**
 * WARNING:Assumption homogen Grid,
 * Compute the first order finite difference operator with centered scheme in di
 *
 * @param i a int, index of point on which we compute finite differencial operat
 * @param dir a int, direction in which we compute finite differencial operator
 * @param v a PnlVect pointer of nodal coefficients in direction dir
 * and hierarchic coefficients in others directions
 * @param G a GridSparse pointer
 * @return a double equal to the discret finite difference operator
 */
/*Assumption homogen Grid */
double FD_Conv_Center(const int i, const int dir,
                    const PnlVect *v,
                    const GridSparse *G)
{
    int *Ind_neig;
    int PP[3] = {dir, i, 0};
    Ind_neig = pnl_hmat_int_lget(G->Ind_Neigh, PP);
    return FD_Conv_Stencil_Center(i, dir, v, G, *Ind_neig, *(Ind_neig + 1));
}

/**
 * WARNING:Assumption homogen Grid,
 * Compute the first order finite difference operator with decentered scheme in
 * we use upwind scheme base of sign of coeff.
 *
 * @param i a int, index of point on which we compute finite differencial operat
 * @param dir a int, direction in which we compute finite differencial operator
 * @param v a PnlVect pointer of nodal coefficients in direction dir

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* and hierarchic coefficients in others directions
* @param G a GridSparse pointer
* @param coeff a double, use to compute the good decentered scheme
* to have stabilisation properties on matrix operator
* @return a double equal to the discret finite difference operator
*/
double FD_Conv_DeCenter(const int i, const int dir,
                        const PnlVect *v,
                        const GridSparse *G,
                        const double coeff)
{
    double Res;
    int Ind_neig;
    int PP[3] = {dir, 2, 0};
    PP[2] = (coeff > 0) ? 1 : 0;
    Ind_neig = pnl_hmat_int_get(G->Ind_Neigh, PP);
    Res = FD_Conv_Stencil_DeCenter(i, dir, v, G, Ind_neig);
    Res *= (coeff > 0) ? 1 : -1;
    return Res;
}

/*
* Compute a function on a sparse grid
*
* @param G a GridSparse pointer
* @param Vout a PnlVect pointer of nodal coefficients, equal to apply(x).
* @param apply a function, the function interpolet on the sparse grid
*/
void GridSparse_apply_function(GridSparse *G, PnlVect *Vout, double (*apply)(const
{
    int i;
    PnlVectInt *Current = pnl_vect_int_create(0);
    PnlVect *X = pnl_vect_create_from_zero(G->dim);
    for (i = 1; i < G->size; i++)
    {
        pnl_mat_int_get_row(Current, G->Points, i);
        vect_int_dyadic_cast(Current, X);
        LET(Vout, i) = premia_pde_dim_boundary_eval_from_unit(apply, G->Bnd, X);
    }
    pnl_vect_int_free(&Current);
}

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    pnl_vect_free(&X);
}

/*
 * Print function
 *
 * @param G a GridSparse pointer
 * @param Vout a PnlVect pointer of nodal coefficients,
 * @param file, the file where function is printing.
 */
void GridSparse_fprint(FILE *file, GridSparse *G,
                       PnlVect *Vout)
{
    int i = 1, d = 0;
    /* First point is no good points */
    PnlVect *X = pnl_vect_create_from_zero(G->dim);
    PnlVectInt *Current = pnl_vect_int_create(0);
    while (i < G->size)
    {
        pnl_mat_int_get_row(Current, G->Points, i);
        vect_int_dyadic_cast(Current, X);
        premia_pde_dim_boundary_from_unit_to_real_variable(G->Bnd, X);
        d = 0;
        while (d < X->size)
        {
            /*printf("%d,",d); */
            /*printf("%7.4f ",GET(X,d)); */
            fprintf(file, "%7.4f ", GET(X, d));
            d++;
        };
        /*printf("%7.4f\ n",GET(Vout,i)); */
        fprintf(file, "%7.4f", GET(Vout, i));
        fprintf(file, "\ n");
        i++;
    }
    pnl_vect_int_free(&Current);
    pnl_vect_free(&X);
}

/*//////////////////////////////////// */

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/* Sparse Laplacien Operator */
/*//////////////////////////////////// */

/**
 * Create the sparse operator for Poisson equation
 *
 * @return pointer on LaplacienSparseOp
 */
LaplacienSparseOp *create_laplacien_sparse_operator()
{
    LaplacienSparseOp *Op = malloc(sizeof(LaplacienSparseOp));
    return Op;
}

/**
 * initilisation of the sparse operator for Poisson equation
 *
 * @param Op pointer on LaplacienSparseOp
 */
void initialise_laplacien_sparse_operator(LaplacienSparseOp *Op)
{
    Op->V_tmp0 = pnl_vect_create_from_zero(Op->G->size);
    Op->V_tmp1 = pnl_vect_create_from_zero(Op->G->size);
}

/**
 * desallocation of sparse operator for Poisson equation
 *
 * @param Op pointer on LaplacienSparseOp
 */
void laplacien_sparse_operator_free(LaplacienSparseOp **Op)
{
    pnl_vect_free(&(*Op)->V_tmp0);
    pnl_vect_free(&(*Op)->V_tmp1);
    GridSparse_free(&(*Op)->G);
    free(*Op);
    *Op = NULL;
}

/*

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```

* WARNING: with the convention A is matrix operator, we compute
*  $V_{out} = a * A V_{in} + b V_{out}$ 
*
* @param Op a LaplacienSparseOp contains data for abstract matrix-vector multip
* @param Vin a PnlVec, input parameters
* @param a a double
* @param b a double
* @param Vout a PnlVec, the output
*/
void GridSparse_apply_Laplacien(LaplacienSparseOp *Op, const PnlVect *Vin,
                                const double a,
                                const double b,
                                PnlVect *Vout)
/*Compute laplacien operator on Sparse Grid */
{
    int d, i;
    double scale = b;
    for (d = 0; d < Op->G->dim; d++)
    {
        Hier_to_Nodal_in_dir(d, Vin, Op->V_tmp0, Op->G);
        /*pnl_vect_print(Op->V_tmp0); */
        for (i = 1; i < Op->G->size; i++)
            LET(Op->V_tmp1, i) = FD_Lap_Center(i, d, Op->V_tmp0, Op->G);
        /*pnl_vect_print(Op->V_tmp1); */
        Nodal_to_Hier_in_dir(d, Op->V_tmp1, Op->V_tmp0, Op->G);
        /*pnl_vect_print(Op->V_tmp0); */
        /*pnl_vect_axpby(Vout,scale,Op->V_tmp0,a); */
        pnl_vect_axpby(a, Op->V_tmp0, scale, Vout);
        scale = 1.0;
    }
}

/*
* WARNING: with the convention A is matrix operator, we compute
*  $V_{out} = a * PC V_{in} + b V_{out}$ 
*
* @param Op a LaplacienSparseOp contains data for abstract matrix-vector multip
* @param Vin a PnlVec, input parameters
* @param a a double
* @param b a double
* @param Vout a PnlVec, the output

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```

*/
void GridSparse_apply_Laplacien_PC(LaplacienSparseOp *Op, const PnlVect *Vin,
                                   const double a,
                                   const double b,
                                   PnlVect *Vout)
{
    int i, d;
    double step_h, times_step_h;
    int Index[3]; /*Index[0]=dir, Index[1]= Position Index[2]= left or right */
    int *neig;
    pnl_vect_clone(Vout, Vin);
    Index[2] = 0;
    i = 1;
    do
    {
        times_step_h = 1;
        for (d = 0; d < Op->G->dim; d++)
        {
            Index[0] = d;
            Index[1] = i;
            neig = pnl_hmat_int_lget(Op->G->Ind_Neigh, Index);
            step_h = (1 << (1 * Step(pnl_mat_int_get(Op->G->Points, i, d),
                                                pnl_mat_int_get(Op->G->Points, *neig, d))));
            times_step_h *= step_h;
        }
        LET(Vout, i) /= 1.0; /*sqrt(times_step_h); */
        /*
        times_step_h/
        (1-Op->theta_time_scheme*premia_pde_time_grid_step(Op->TG)*
        jacobi);
        */
        /*printf(" PC = %7.4f and Jacobi = %7.4f \ n",GET(Op->PC,i),Op->theta_time
        i++;
        }
        while (i < Op->G->size);

    }

/*
* Solve FD discret Sparse version of Poisson problem:
* Laplacien Vout = Vin,

```

```

*
* @param Op a LaplacienSparseOp contains data for abstract matrix-vector multip
* @param Vin a PnlVect, the RHS
* @param Vout a PnlVect, the output
*/
void GridSparse_Solve_Laplacien(LaplacienSparseOp *Op, const PnlVect *Vin, PnlVect *Vout)
{
    /*
    PnlGmresSolver* Solver;
    pnl_vect_set_double(Vout,0.0);
    Solver=pnl_gmres_solver_create(Vin->size,200,10,1e-6);
    pnl_gmres_solver_solve((void*)GridSparse_apply_Laplacien,Op,(void*)GridSparse_Solve_Laplacien,Solver,Vin,Vout);
    pnl_gmres_solver_free(&Solver);
    */
    PnlBicgSolver *Solver;
    Solver = pnl_bicg_solver_create(Vin->size, 100, 1e-6);
    pnl_bicg_solver_solve((void *)GridSparse_apply_Laplacien, Op, (void *)GridSparse_Solve_Laplacien,Solver,Vin,Vout);
    pnl_bicg_solver_free(&Solver);
}

void GridSparse_Solve_Operator(GridSparse *G, const PnlVect *Vin, PnlVect *Vout,
                                void (*operator)(GridSparse *, const PnlVect *, const PnlVect *),
                                void (*operator_PC)(GridSparse *, const PnlVect *, const PnlVect *))
{
    PnlBicgSolver *Solver;
    pnl_vect_set_double(Vout, 0.0);
    Solver = pnl_bicg_solver_create(Vin->size, 200, 1e-6);
    pnl_bicg_solver_solve((void *)operator, G, (void *)operator_PC, G, Vout, Vin,
    pnl_bicg_solver_free(&Solver);
}

/*////////////////////////// */
/* Heat Operator on Sparse Grid */
/*////////////////////////// */
/**
* Create the sparse operator for heat equation
*
* @return pointer on HeatSparseOp
*/

```



```

HeatSparseOp *create_heat_sparse_operator(double eta)
{
    HeatSparseOp *Op = malloc(sizeof(HeatSparseOp));
    Op->eta = eta;
    Op->theta_time_scheme = 1;
    return Op;
}

void GridSparse_preconditioner_heat_init(HeatSparseOp *Op)
{
    int i, d;
    double step_h, times_step_h;
    int Index[3]; /*Index[0]=dir, Index[1]= Position Index[2]= left or right */
    int *neig;
    Index[2] = 0;
    i = 1;
    do
    {
        times_step_h = 0;
        for (d = 0; d < Op->G->dim; d++)
        {
            Index[0] = d;
            Index[1] = i;
            neig = pnl_hmat_int_lget(Op->G->Ind_Neigh, Index);
            step_h = Domain_Size(Op->G, d) * (1 << (Step(pnl_mat_int_get(Op->G->Po
                pnl_mat_int_get(Op->G->Points,
            times_step_h += step_h * step_h;
        }
        LET(Op->PC, i) = 1.0; /*times_step_h; */
        /*
        times_step_h/
        (1-Op->theta_time_scheme*premia_pde_time_grid_step(Op->TG)*
        jacobi);
        */
        /*printf(" PC = %7.4f and Jacobi = %7.4f \ n",GET(Op->PC,i),Op->theta_time
        i++;
    }
    while (i < Op->G->size);
}

```

```

/**
 * initilisation of the sparse operator for heat equation
 *
 * @param Op pointer on HeatSparseOp
 */
void initialise_heat_sparse_operator(HeatSparseOp *Op)
{
    Op->V_tmp0 = pnl_vect_create_from_zero(Op->G->size);
    Op->V_tmp1 = pnl_vect_create_from_zero(Op->G->size);
    Op->PC = pnl_vect_create_from_zero(Op->G->size);
    GridSparse_preconditioner_heat_init(Op);
}

/**
 * deallocation of sparse operator for heat equation
 *
 * @param Op pointer on HeatSparseOp
 */
void heat_sparse_operator_free(HeatSparseOp **Op)
{
    premia_pde_time_grid_free(&(*Op)->TG);
    pnl_vect_free(&(*Op)->V_tmp0);
    pnl_vect_free(&(*Op)->V_tmp1);
    pnl_vect_free(&(*Op)->PC);
    GridSparse_free(&(*Op)->G);
    free(*Op);
    *Op = NULL;
}

/*
 * WARNING: with the convention  $A$  is matrix operator, we compute
 *  $V_{out} = a * A V_{in} + b V_{out}$ 
 * Here  $A = (Mass + sign \Delta_t Laplacien\_FD\_Operator)$ 
 *
 * @param Op a HeatSparseOp contains data for abstract matrix-vector multiplicat
 * @param Vin a PnlVec, input parameters
 * @param a a double
 * @param b a double
 * @param Vout a PnlVec, the output
 */
void GridSparse_apply_heat(HeatSparseOp *Op, const PnlVect *Vin,

```

```

                                const double a,
                                const double b,
                                PnlVect *Vout)
{
    int d, i;
    double sg_delta = 0.5 * a * Op->eta * Op->eta * Op->theta_time_scheme * premia
    /*>> Do V_out = a Mass V_in + b Vout */
    /*pnl_vect_axpby(Vout,b,Vin,a); */
    pnl_vect_axpby(a, Vin, b, Vout);
    /*>> Do V_out += a Op V_in */
    for (d = 0; d < Op->G->dim; d++)
    {
        Hier_to_Nodal_in_dir(d, Vin, Op->V_tmp0, Op->G);
        for (i = 1; i < Op->G->size; i++)
            LET(Op->V_tmp1, i) = FD_Lap_Center(i, d, Op->V_tmp0, Op->G);
        Nodal_to_Hier_in_dir(d, Op->V_tmp1, Op->V_tmp0, Op->G);
        pnl_vect_axpby(sg_delta, Op->V_tmp0, 1.0, Vout);
    }
}

/*
 * WARNING: with the convention A is matrix operator, we compute
 * V_out = a * PC V_in + b Vout
 *
 * @param Op a HeatSparseOp contains data for abstract matrix-vector multiplicat
 * @param Vin a PnlVec, input parameters
 * @param a a double
 * @param b a double
 * @param Vout a PnlVec, the output
 */
void GridSparse_apply_heat_PC(HeatSparseOp *Op, const PnlVect *Vin,
                                const double a,
                                const double b,
                                PnlVect *Vout)
{
    pnl_vect_axpby(1.0, Vin, 0.0, Vout);
    pnl_vect_mult_vect_term(Vout, Op->PC);
}

/*
 * Solve FD discret Sparse version of Heat problem with theta-scheme in time

```

```

* Vout - theta delta_t 1/2 Laplacien_Operator Vout
* = Vin + (1- theta) delta_t 1/2 Laplacien_Operator Vin,
*
* @param Op a HeatSparseOp contains data for abstract matrix-vector multiplicat
* @param Vin a PnlVec, the RHS
* @param Vout a PnlVec, the output
*/
void GridSparse_Solve_heat(HeatSparseOp *Op, const PnlVect *Vin, PnlVect *Vout)
{

    PnlVect *V_rhs;
    PnlBicgSolver *Solver;
    double theta = 0.0;
    V_rhs = pnl_vect_create_from_zero(Vin->size);
    pnl_vect_clone(Vout, Vin);
    Solver = pnl_bicg_solver_create(Vin->size, 200, 1e-6);
    premia_pde_time_start(Op->TG);
    do
    {
        Op->theta_time_scheme = theta;
        GridSparse_apply_heat(Op, Vout, 1.0, 0.0, V_rhs);
        Op->theta_time_scheme = -1.0 + theta;
        pnl_bicg_solver_solve((void *)GridSparse_apply_heat,
                               Op, (void *)
                               GridSparse_apply_heat_PC,
                               Op, Vout, V_rhs, Solver);
    }
    while (premia_pde_time_grid_increase(Op->TG));
    pnl_bicg_solver_free(&Solver);
    pnl_vect_free(&V_rhs);
}

#undef SPARSE_N2H
#undef SPARSE_H2N
#undef SPARSE_N2H_FUNC

```