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```
#ifndef __levy_diffusion__
#define __levy_diffusion__

#include "pnl/pnl_vector.h"
#include "pnl/pnl_band_matrix.h"
#include "pnl/pnl_tridiag_matrix.h"

extern dcomplex Ctgamma_log(dcomplex z);

typedef struct _Heston_diffusion Heston_diffusion;

struct _Heston_diffusion
{
    double Eta;
    double Kappa;
    double Rho;
    double Theta;
    double Sigma;
    double sigma_sqr;
    double theta_sqr;
    double sigma_sqr_d_eta_kappa;
    double etakappathetam2;
    double rho_theta;
    double Drift;
    int nb_parameters;
};

extern Heston_diffusion *Heston_diffusion_create(double Eta_, double Kappa_, double
    double Theta_, double Sigma_,
    double *jump_drift);

extern void Heston_diffusion_list(const Heston_diffusion *process);
extern dcomplex Heston_diffusion_characteristic_exponent(dcomplex u, double t, v
extern dcomplex Heston_diffusion_ln_characteristic_function(dcomplex u, double t

/*

dS_t = (r-q-\ lambda_y \ mu) S_t dt + \ sqrt{V_t} S_t dW_t^1 + J_y S_t dq_y(t)
dV_t = \ kappa_{nu} \ left( \ eta_{nu} + V_t \ right) + \ theta_{nu} \ sqrt{V_t}
```

```

dW^1 dW^2 = \ rho dt

(1+J_y) is a lognormally distributed with mean $\ mu_y$ and variance
$\ sigma_y^2$

$q_{y}$ is an independent Poisson process with arrival rate
$\ lambda_{y}$
$\ mu= \ left( \ exp{\ \ mu_y+\ \ sigma_y^2/2}-1\ right).$

*/

typedef struct _Bates_diffusion Bates_diffusion;

struct _Bates_diffusion
{
    double Eta;
    double Kappa;
    double Theta;
    double Rho;
    double Sigma;

    double mu_J;
    double Sigma_J;
    double Lambda_J;

    double sigma_sqr;
    double theta_sqr;
    double sigma_sqr_d_eta_kappa;
    double etakappathetam2;
    double rho_theta;
    double lnepmu_j;
    double sigma_j_sqr_demi;
    double Drift;
    int nb_parameters;
};

extern Bates_diffusion *Bates_diffusion_create(double Eta_, double Kappa_, double
    double Theta_, double Sigma_,
    double mu_J_,
    double Sigma_J_, double Lambda_J_, double *jump_drift);

```

```
extern dcomplex Bates_diffusion_characteristic_exponent(dcomplex u, double t, vo
extern dcomplex Bates_diffusion_ln_characteristic_function(dcomplex u, double t,
/*
```

```
@article {MR1841412,
  AUTHOR = {Barndorff-Nielsen, Ole E. and Shephard, Neil},
  TITLE = {Non-{G}aussian {O}rstein-{U}hlenbeck-based models and some of
    their uses in financial economics},
  JOURNAL = {J. R. Stat. Soc. Ser. B Stat. Methodol.},
  FJOURNAL = {Journal of the Royal Statistical Society. Series B.
    Statistical Methodology},
  VOLUME = {63},
  YEAR = {2001},
  NUMBER = {2},
  PAGES = {167--241},
  ISSN = {1369-7412},
  MRCLASS = {62M07 (62M09 62M10 62P20)},
  MRNUMBER = {MR1841412 (2002c:62127)},
}
```

The square volatility follows the SDE of the form :

$$d\sigma^2_t = -\lambda \sigma^2_t dt + dZ_{\lambda t}$$

where $\lambda > 0$ and Z is a subordinator.

The risk neutral dynamic of the log price $x_t = \log S_t$ are given by

$$dW_t = (r - q - \lambda k(-\rho) - \sigma^2/2) dt + \sigma_t dW_t + \rho dZ_t$$

$$\quad x_0 = \log(S_0).$$

where $k(u) = \log\{\mathbb{E}[\exp(-u Z_1)]\}$.

Choice Z_t as a compound poisson process,

$$Z_t = \sum_{n=1}^{N_t} x_n$$

where N_t is a Poisson process with intensity parameter α

and each x_n follows an exponential law with mean $\frac{1}{\beta}$.

One can show that the process σ^2_t is a stationary process with a marginal law that follows a Gamma distribution with mean α and variance $\frac{\alpha}{\beta}$. In this case,

$$k(u) = \frac{-\alpha}{\beta + u}.$$

```
*/
```

```
typedef struct _BNS_diffusion BNS_diffusion;
```

```
struct _BNS_diffusion
```

```

{
    double Lambda;
    double Rho;
    double Beta;
    double Alpha;
    double Sigma0;

    double Sigma0_sqr ;
    double Lambda_m1;
    double Drift; // proportional to Drift correction
    int nb_parameters;
};

extern BNS_diffusion *BNS_diffusion_create(double Lambda_, double Rho_,
    double Beta_, double Alpha_,
    double Sigma0_, double *jump_drift);
extern dcomplex BNS_diffusion_characteristic_exponent(dcomplex u, double t, void
extern dcomplex BNS_diffusion_ln_characteristic_function(dcomplex u, double t, v
extern void BNS_diffusion_list(const BNS_diffusion *process);

/*
    @article {MR1793362,
        AUTHOR = {Duffie, Darrell and Pan, Jun and Singleton, Kenneth},
        TITLE = {Transform analysis and asset pricing for affine
            jump-diffusions},
        JOURNAL = {Econometrica},
        FJOURNAL = {Econometrica. Journal of the Econometric Society},
        VOLUME = {68},
        YEAR = {2000},
        NUMBER = {6},
        PAGES = {1343--1376},
        ISSN = {0012-9682},
        CODEN = {ECMTA7},
        MRCLASS = {91B28 (60J60)},
        MRNUMBER = {MR1793362 (2001m:91081)},
    }


$$dS_t = (r - q - \lambda_y \mu) S_t dt + \sqrt{V_t} S_t dW_t^1 + J_y S_t dq_y(t) \setminus$$


$$dV_t = \kappa_{\nu} \left( \eta_{\nu} + V_t \right) + \theta_{\nu} \sqrt{V_t} dW_t^2 + J_V dq_{\nu}(t)$$


```

$dW^1 dW^2 = \rho dt$

$(1+J_y)$ is a lognormally distributed with mean μ_y and variance σ_y^2

J_V has an exponential distribution with mean μ_{ν}

q_y and q_{ν} are independent Poisson process with arrivals rates λ_y and λ_{ν}

$\mu = \left(\exp(\mu_y + \sigma_y^2/2) - 1 \right)$

*/

typedef struct _DPS_diffusion DPS_diffusion;

```
struct _DPS_diffusion
{
    double Eta;
    double Kappa;
    double Rho;
    double Theta;
    double Sigma;

    double mu_y;
    double Sigma_y_sqr_demi;
    double Lambda_y;

    double mu_v;
    double Lambda_v;

    double sigma_cy_sqr_demi;
    double mu_cy;
    double mu_cv;
    double Lambda_c;
    double rho_j;

    double s_lambda;
}
```

```

double sigma_sqr;
double theta_sqr;
double sigma_sqr_d_eta_kappa;
double etakappathetam2;
double rho_theta;

double Drift;
int nb_parameters;
};

extern DPS_diffusion *DPS_diffusion_create(double Eta_, double Kappa_,
double Rho_, double Theta_,
double Sigma_, double mu_y_,
double Sigma_y_, double Lambda_y_,
double mu_v_, double Lambda_v_,
double mu_cy_, double Sigma_cy_,
double mu_cv_, double Lambda_c_,
double rho_j_, double *jump_drift);
extern dcomplex DPS_diffusion_characteristic_exponent(dcomplex u, double t, void
extern dcomplex DPS_diffusion_ln_characteristic_function(dcomplex u, double t, v
extern void DPS_diffusion_list(const DPS_diffusion *model);

/*
The two following class of model come from :

@article {MR1995283,
AUTHOR = {Carr, Peter and Geman, H{\ 'e}lyette and Madan, Dilip B. and
Yor, Marc},
TITLE = {Stochastic volatility for {L}\ 'evy processes},
JOURNAL = {Math. Finance},
FJOURNAL = {Mathematical Finance. An International Journal of Mathematics,
Statistics and Financial Economics},
VOLUME = {13},
YEAR = {2003},
NUMBER = {3},
PAGES = {345--382},
ISSN = {0960-1627},
MRCLASS = {91B28 (60G51)},

```

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MRNUMBER = {MR1995283 (2005a:91054)},
}

CIR stochastic clock

the CIR process can be use as rate of time change. it follows the SDE


$$dy_t = \kappa (\eta - y_t) dt + \lambda \sqrt{y_t} dW_t$$


*/
typedef struct _CIR_diffusion CIR_diffusion;

struct _CIR_diffusion
{
    double Kappa;
    double Eta;
    double Lambda;
    double y0;
    double Drift; // proportional to Drift correction
    double Kappa_sqr;
    double Lambda_sqr;
    double Kappa_sqr_eta_div_lambda_sqr;
    double Two_kappa_eta_div_lambda_sqr;

    double time;
    double Jump_drift;
    double Jump_drift_psi;
    int nb_parameters;
    void *Levy;
    dcomplex(*characteristic_exponent)(dcomplex u, void *mod);
};

extern CIR_diffusion *CIR_diffusion_create(double Kappa, double Eta, double Lambda,
    void *Levy_,
    dcomplex(*characteristic_exponent_)(dcomplex, void *),
    double *jump_drift);

extern void CIR_diffusion_list(const CIR_diffusion *process);

extern dcomplex CIR_diffusion_characteristic_exponent(dcomplex u, double t, void

```

```

extern dcomplex CIR_diffusion_ln_characteristic_function(dcomplex u, double t, void *Process);
extern double CIR_diffusion_get_sigma_square(CIR_diffusion *Process);
extern void CIR_diffusion_fourier_stiffness(CIR_diffusion *mod, double hx, double htau, double t);
extern void CIR_diffusion_update_time(CIR_diffusion *process, double t);
/*

Gamma- OU stochastic clock

the rate of time change is now solution of the SDE


$$dy_t = -\lambda y_t dt + dz_{\{\lambda t\}}$$


Choice  $z_t$  as a compound poisson process,
 $z_t = \sum_{n=1}^{N_t} x_n$ 
where  $N_t$  is a Poisson process with intensity parameter  $\alpha$ 
and each  $x_n$  follows an exponential law with mean  $\frac{1}{\beta}$ .
*/
typedef struct _GammaOU_diffusion GammaOU_diffusion;

struct _GammaOU_diffusion
{
    double Lambda;
    double Alpha;
    double Beta;
    double y0;
    double Drift; // proportional to Drift correction

    double Lambda_a;
    double Lambda_b;
    double y0_one_m_el_div_lambda;
    double y0_el;
    double one_m_el_div_lambda;
    double beta_el;

    double time;
    double Jump_drift;
    double Jump_drift_psi;
    int nb_parameters;
    void *Levy;
    dcomplex(*characteristic_exponent)(dcomplex u, void *mod);

```



```

};

extern GammaOU_diffusion *GammaOU_diffusion_create(double Lambda, double Alpha,
    void *Levy_,
    dcomplex(*characteristic_exponent_)(dcomplex, void *),
    double *jump_drift);
extern dcomplex GammaOU_diffusion_characteristic_exponent(dcomplex u, double t,
extern dcomplex GammaOU_diffusion_ln_characteristic_function(dcomplex u, double t,
extern double GammaOU_diffusion_get_sigma_square(GammaOU_diffusion *Process);
extern void GammaOU_diffusion_fourier_stiffness(GammaOU_diffusion *mod, double h);
extern void GammaOU_diffusion_update_time(GammaOU_diffusion *process, double t);
extern void GammaOU_diffusion_list(const GammaOU_diffusion *process);

extern void test_CIR_diffusion(void);
extern void test_GammaOU_diffusion(void);

typedef struct _Levy_diffusion Levy_diffusion;

struct _Levy_diffusion
{
    void *process;
    int nb_parameters;
    int type_model;
    dcomplex(*characteristic_exponent)(dcomplex u, double t, void *mod);
    dcomplex(*ln_characteristic_function)(dcomplex u, double t, void *mod);
    // Artificial volatility term to come back to parabolic problem
    double vol_square;
};

extern Levy_diffusion *Levy_diffusion_create(void *process_, dcomplex(*characteristic_exponent_)(dcomplex u, double t, void *mod),
    dcomplex(*ln_characteristic_function_)(dcomplex u, double t, void *mod));
extern Levy_diffusion *Levy_diffusion_create_from_vect(int model, const double *parameters);
extern void Levy_diffusion_free(Levy_diffusion **Levy);
extern dcomplex Levy_diffusion_characteristic_exponent(dcomplex u, double t, Levy_diffusion *Levy);
extern double Levy_diffusion_get_sigma_square(Levy_diffusion *Levy);
extern void Levy_diffusion_fourier_stiffness(Levy_diffusion *mod, double t, double h);
extern dcomplex Levy_diffusion_ln_characteristic_function(dcomplex u, double t, Levy_diffusion *Levy);
extern dcomplex Levy_diffusion_ln_characteristic_function_with_cast(dcomplex u, double t, Levy_diffusion *Levy);
//extern dcomplex Levy_diffusion_characteristic_function(dcomplex u, double t, Levy_diffusion *Levy);

```

```
extern void Levy_diffusion_constraints(PnlVect *res, const Levy_diffusion *Levy)

#endif
```