In [43]:

```
import numpy as np
import matplotlib.pyplot as plt
from sympy import *
```

In [44]:

```
def random_direction(size):
    vec = np.random.uniform(-1, 1, size=size)
    return vec/np.linalg.norm(vec)


def objective(x, q=1):
    if q == 1:
        return 100*(x[1] - x[0]**2)**2 + (1-x[0])**2
    elif q == 2:
        return (x[0] + 2*x[1] - 7)**2 + (2*x[0] + x[1] - 5)**2
    else:
        raise ValueError('Bad question number')


def find_best_lambda(x, lbd, q):
    sol = solve(diff(objective(x, q)), lbd)
    sol = np.array([float(re(i)) for i in sol])
    hess = diff(diff(objective(x, 1)))
    hess_vals = np.array([float(hess.evalf(subs={lbd: i})) for i in sol])

    candidates = [i for i in range(len(sol)) if hess_vals[i] > 0]
    hess_vals = [hess_vals[i] for i in candidates]

    try:
        return sol[candidates[np.argmax(hess_vals)]]
    except:
        return 'None'


def random_walk(x_0, q):

    # Parameters to start off
    x_0 = np.asarray(x_0)
    x = x_0
    u = random_direction(x.shape)

    # Other controllers
    count = 0
    feasible_count = 0
    done = False
    lbd = Symbol('lambda')

    # Movement of point
    points = []

    # Loop
    while not done:

        # Find next symbolic point
        x_symb = x + lbd * u

        # Find best lambda and compute new vector
        step_size = find_best_lambda(x_symb, lbd, q)

        if isinstance(step_size, str):
            break
        else:
            x_new = x + step_size * u

```

```
        # Decision
        if objective(x_new, q) < objective(x, q):
            x = x_new
            feasible_count += 1
        elif objective(x_new, q) >= objective(x, q):
            u = random_direction(x.shape)

        if count % 100 == 0:
            print("Iteration {:3d} - x {} - f(x) {:.5f}".format(
                count, x, objective(x, q)
            ))
        points.append(x)

        count += 1
        if count > 1000:
            done = True

    return x, feasible_count, np.array(points)
```

In [45]:

```
opt, feasible_count, points = random_walk([-0.5, 0.5], q=1)
```

```
Iteration   0 - x [-0.52209969  0.27393826] - f(x) 2.31697
Iteration 100 - x [1.32433764 1.75588291] - f(x) 0.10560
Iteration 200 - x [0.90004706 0.80980368] - f(x) 0.01000
Iteration 300 - x [0.94055993 0.88448703] - f(x) 0.00354
Iteration 400 - x [0.94074379 0.88493894] - f(x) 0.00351
Iteration 500 - x [0.94074379 0.88493894] - f(x) 0.00351
Iteration 600 - x [0.94074379 0.88493894] - f(x) 0.00351
Iteration 700 - x [0.96103528 0.92363284] - f(x) 0.00152
Iteration 800 - x [0.96103528 0.92363284] - f(x) 0.00152
Iteration 900 - x [0.96103528 0.92363284] - f(x) 0.00152
Iteration 1000 - x [0.96103528 0.92363284] - f(x) 0.00152
```

In [49]:

```
opt
```

Out[49]:

```
array([0.96103528, 0.92363284])
```

In [50]:

```
feasible_count
```

Out[50]:

```
873
```

In [46]:

```
final_points = [[-0.5, 0.5]]
for i in points.tolist():
    if i in final_points:
        continue
    else:
        final_points.append(i)

final_points = np.array(final_points)
```

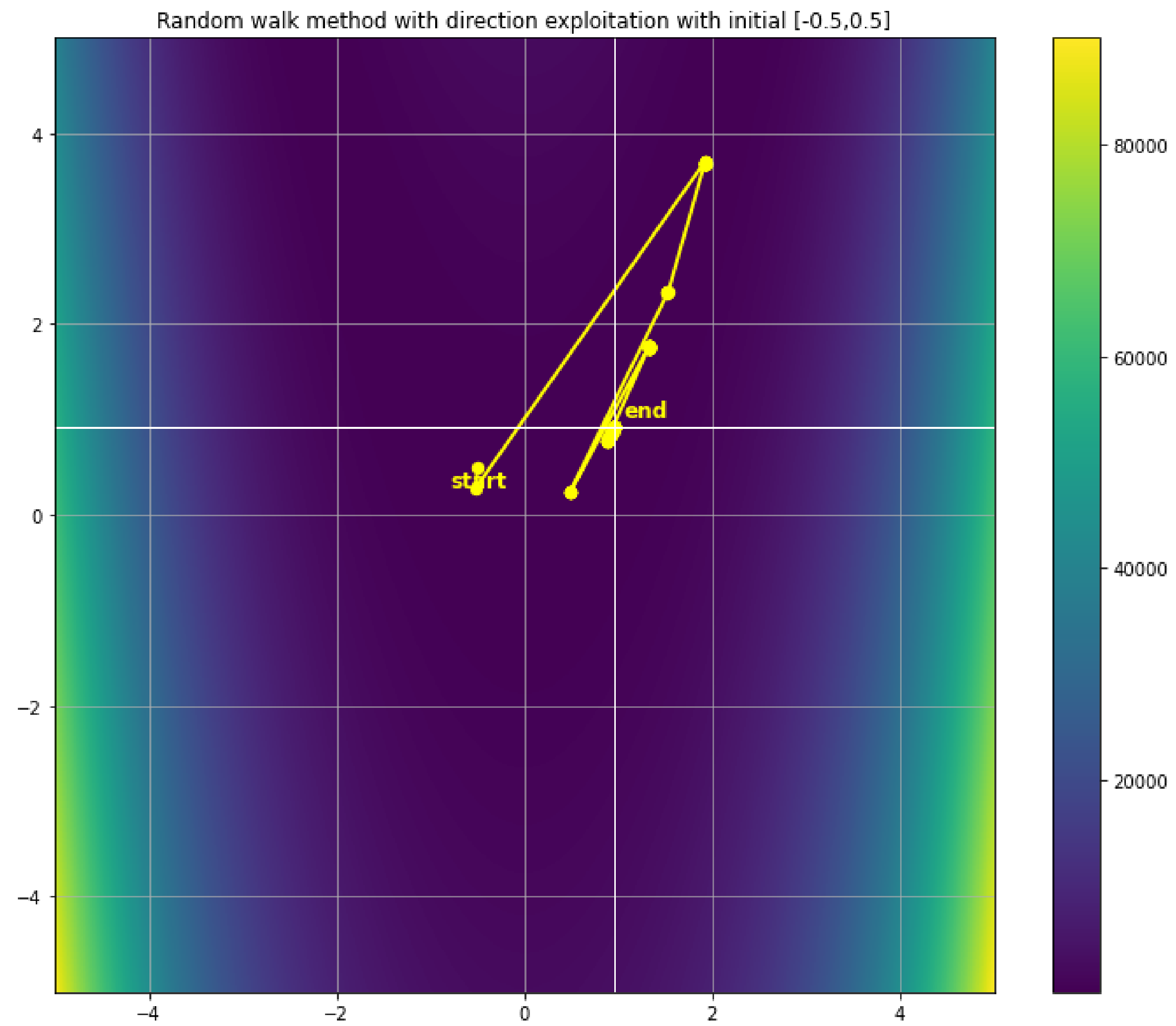
In [51]:

```
def track_movements(q, points):
    x = np.linspace(-5, 5, 1000)
    y = np.linspace(-5, 5, 1000)
    xx, yy = np.meshgrid(x, y)
    zz = np.array([objective(a, q) for a in np.c_[xx.ravel(), yy.ravel()]])
    zz = zz.reshape(xx.shape)

    plt.figure(figsize=(12, 10))
    plt.pcolormesh(xx, yy, zz)
    plt.colorbar()
    plt.plot(points[:, 0], points[:, 1], color='yellow', linewidth=2)
    plt.scatter(points[:, 0], points[:, 1], c='yellow', s=40, edgecolor='yellow')
    plt.text(points[0][0]-0.3, points[0][1]-0.2, 'start', color='yellow', fontsize=12,
    plt.text(points[-1][0]+0.1, points[-1][1]+0.1, 'end', color='yellow', fontsize=12,
    plt.axvline(points[-1][0], ymin=0, ymax=1, color='white', linewidth=1)
    plt.axhline(points[-1][1], xmin=0, xmax=1, color='white', linewidth=1)
    plt.grid(alpha=0.8)
    plt.title('Random walk method with direction exploitation with initial [-0.5,0.5]')
    plt.show()
```

In [52]:

```
track_movements(1, final_points)
```



In [53]:

```
opt, feasible_count, points = random_walk([0, 0], q=2)
```

```
Iteration   0 - x [1.94351601 2.06270114] - f(x) 1.76891
```

In [54]:

```
opt
```

Out[54]:

```
array([1.06874236, 2.94175084])
```

In [55]:

```
feasible_count
```

Out[55]:

```
5
```

In [56]:

```
final_points = [[0, 0]]
for i in points.tolist():
    if i in final_points:
        continue
    else:
        final_points.append(i)

final_points = np.array(final_points)
```

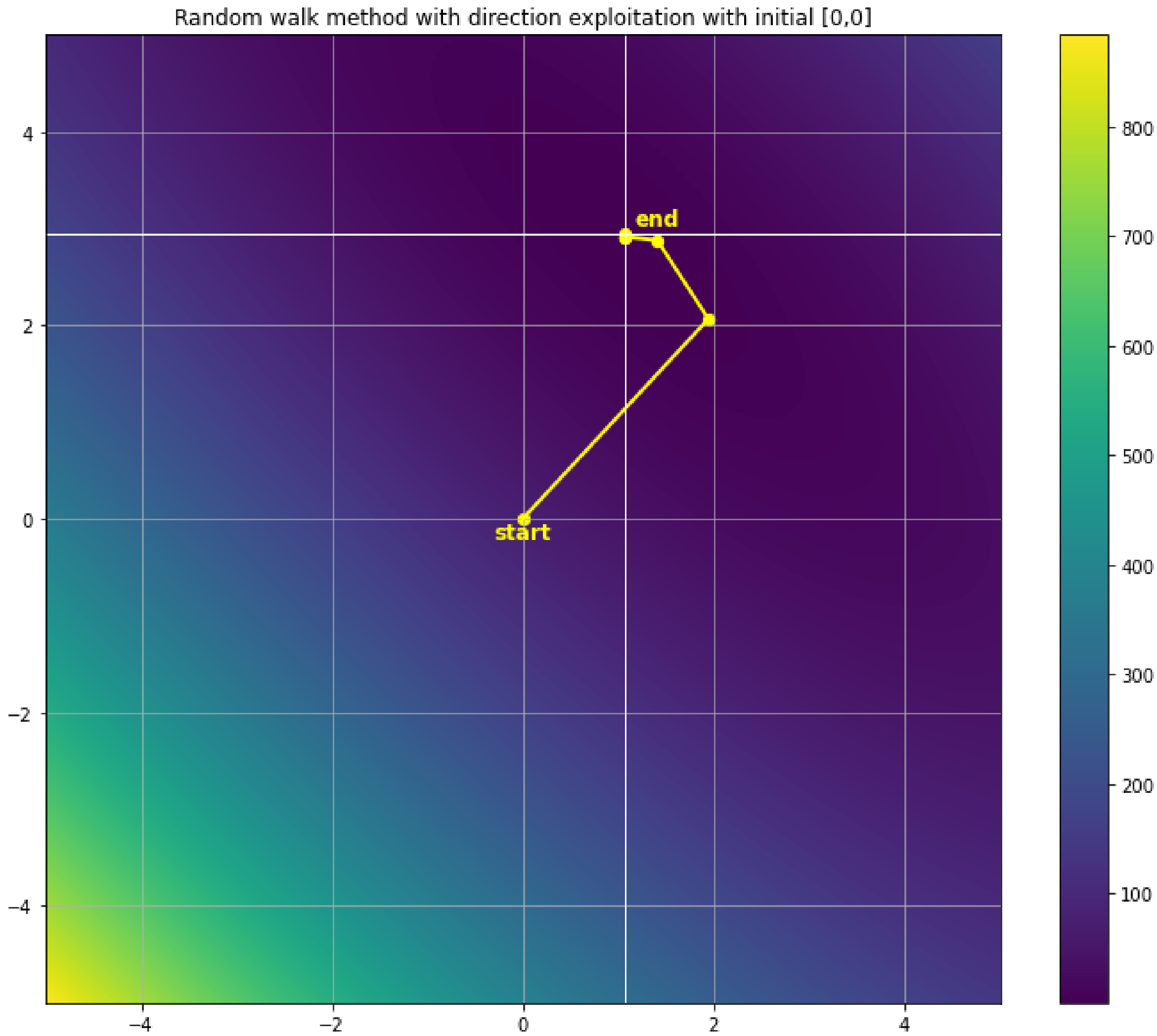
In [57]:

```
def track_movements(q, points):
    x = np.linspace(-5, 5, 1000)
    y = np.linspace(-5, 5, 1000)
    xx, yy = np.meshgrid(x, y)
    zz = np.array([objective(a, q) for a in np.c_[xx.ravel(), yy.ravel()]])
    zz = zz.reshape(xx.shape)

    plt.figure(figsize=(12, 10))
    plt.pcolormesh(xx, yy, zz)
    plt.colorbar()
    plt.plot(points[:, 0], points[:, 1], color='yellow', linewidth=2)
    plt.scatter(points[:, 0], points[:, 1], c='yellow', s=40, edgecolor='yellow')
    plt.text(points[0][0]-0.3, points[0][1]-0.2, 'start', color='yellow', fontsize=12,
    plt.text(points[-1][0]+0.1, points[-1][1]+0.1, 'end', color='yellow', fontsize=12,
    plt.axvline(points[-1][0], ymin=0, ymax=1, color='white', linewidth=1)
    plt.axhline(points[-1][1], xmin=0, xmax=1, color='white', linewidth=1)
    plt.grid(alpha=0.8)
    plt.title('Random walk method with direction exploitation with initial [0,0]')
    plt.show()
```

In [58]:

```
track_movements(2, final_points)
```



In [377]:

```
objective([0.9979, 3.0016], 2)
```

Out[377]:

```
7.969999999999089e-06
```

In [ ]:

```

```