

广义线性非完整力学系统的 Hojman 守恒量^{*}

董文山^{1)†} 方建会²⁾ 黄宝歆¹⁾

1) (潍坊学院物理与电子科学系, 潍坊 261061)

2) (中国石油大学应用物理系, 东营 257061)

(2009 年 4 月 18 日收到; 2009 年 5 月 19 日收到修改稿)

研究广义线性非完整力学系统的 Lie 对称性导致的 Hojman 守恒量, 在时间不变的特殊 Lie 对称变换下, 给出系统的 Lie 对称性确定方程、约束限制方程和附加限制方程, 得到相应完整系统的 Hojman 守恒量以及广义线性非完整力学系统的弱 Hojman 守恒量和强 Hojman 守恒量, 并举一算例说明结果的应用.

关键词: 广义线性非完整力学系统, Lie 对称性, Hojman 守恒量

PACC: 0320, 1110, 0220

1. 引言

力学系统的守恒量不仅具有数学上的重要性, 而且能折射出深刻的物理规律, 它在理论物理和力学的研究中起着极其重要的作用. 近代寻求力学系统守恒量的方法, 主要有 Noethe 对称性、Lie 对称性和形式不变性, 由这三类对称性导致守恒量的研究已取得了许多重要成果^[1-9].

1992 年, Hojman^[10] 利用运动微分方程在时间不变的无限小变换下的不变性直接导致了一类新型守恒量——Hojman 守恒量, 近年来, 这种用 Lie 对称性直接寻求动力学系统守恒量的方法受到学术界的关注, 被拓展到了 Lagrange 系统^[11]、Hamilton 系统^[12,13]、Birkhoff 系统^[14]、线性非完整力学系统^[15]、变质量系统^[16,17]和广义经典力学系统^[18]. 本文将这一方法推广至广义线性非完整力学系统, 在时间不变的特殊 Lie 对称变换下, 给出系统的 Lie 对称性确定方程、约束限制方程和附加限制方程, 得到相应完整系统的 Hojman 守恒量以及广义线性非完整力学系统的弱 Hojman 守恒量和强 Hojman 守恒量存在的条件和形式, 并举一算例说明结果的应用.

2. 系统的运动微分方程

研究自由度为 n 的广义线性非完整力学系统. 假设系统的位形由 n 个广义坐标 $q_s (s = 1, \dots, n)$ 确定, 其运动受有 g 个 k 阶线性非完整约束

$$f_\beta \left(t, q_s, \dot{q}_s, \dots, q_s^{(k)} \right) = 0 \quad (\beta = 1, 2, \dots, g). \quad (1)$$

在广义复合导数空间, 系统的虚位移满足广义非完整力学的 Чераев 定义^[19]

$$\sum_{s=1}^n \sum_{m=1}^k \frac{\partial f_\beta}{\partial q_s^{(m)}} \delta^{(m-1)} q_s = 0, \quad \delta t = 0, \delta^{(m-1)} q_s \neq 0 \quad (m = 1, \dots, k). \quad (2)$$

由文献[19], 系统的 Routh 方程为

$$\sum_{m=1}^k (-1)^{m+1} \frac{d^m}{dt^m} \left(\frac{\partial L}{\partial q_s^{(m)}} \right) - \frac{\partial L}{\partial q_s} = \sum_{\beta=1}^g \sum_{m=1}^k \lambda_\beta^m \frac{\partial f_\beta}{\partial q_s}, \quad (3)$$

式中 $L = L \left(t, q_s, \dot{q}_s, \dots, q_s^{(k)} \right)$ 为广义 Lagrange 函数, λ_β^m 为广义 Lagrange 待定乘子, 在 (3) 式积分之前, 可由 (1) 和 (3) 式先求出约束乘子 λ_β^m 作为 $q_s^{(m)}, q_s^{(m-1)}$ 的函数, 于是 (3) 式可表为相应完整系统的形式

^{*} 潍坊学院自然科学基金 (批准号: 2008Z03) 资助的课题.

[†] E-mail: dongwenshan@126.com

$$\sum_{m=1}^k (-1)^{m+1} \frac{d^m}{dt^m} \left(\frac{\partial L}{\partial q_s^{(m)}} \right) - \frac{\partial L}{\partial q_s} = \Lambda_s,$$
$$\Lambda_s = \sum_{m=1}^k \Lambda_s^m = \sum_{\beta=1}^g \sum_{m=1}^k \lambda_{\beta}^m \frac{\partial f_{\beta}}{\partial q_s^{(m)}} \quad (s = 1, \cdots, n).$$
(4)

引进广义动量和 Hamiltonian^[20]

$$p_{s/m} = \sum_{j=0}^{k-m} (-1)^j \frac{d^j}{dt^j} \frac{\partial L}{\partial q_s^{(j+m)}}, \quad (5)$$

$$H \left(q_s^{(m-1)}, p_{s/m}, t \right) = \sum_{s=1}^n \sum_{m=1}^k p_{s/m} q_s^{(m)} - L, \quad (6)$$

则系统运动方程可写成正则形式

$$q_s^{(m)} = \frac{\partial H}{\partial p_{s/m}}, \quad \dot{p}_{s/m} = - \frac{\partial H}{\partial q_s^{(m-1)}} + \tilde{\Lambda}_s$$
$$(s = 1, \cdots, n; m = 1, \cdots, k), \quad (7)$$

$$\tilde{\Lambda}_s \left(q_s^{(m-1)}, p_{s/m}, t \right) = \sum_{\beta=1}^g \sum_{m=1}^k \lambda_{\beta}^m \left(q_s^{(m-1)}, q_s^{(m)} \right) \times \left(q_s^{(m-1)}, p_{s/m}, t \right) \left(\frac{\partial f_{\beta}}{\partial q_s^{(m)}} \right), \quad (8)$$

其中, $\tilde{\Lambda}_s$ 为广义非完整约束反力 Λ_s 中 $q_s^{(m)}$ 用 $\left(q_s^{(m-1)}, p_{s/m}, t \right)$ 替代所得表达式. 引入 $2nk$ 个分量的逆变向量^[21, 22]

$$a^{\mu} = \begin{cases} q_s^{(m-1)} & (\mu = (2m-2)n + s; \\ & m = 1, \cdots, k; s = 1, \cdots, n), \\ p_{s/m} & (\mu = (2m-1)n + s; \\ & m = 1, \cdots, k; s = 1, \cdots, n), \end{cases} \quad (9)$$

$$R_{\mu} = \begin{cases} p_{s/m} & (\mu = (2m-2)n + s; \\ & m = 1, \cdots, k; s = 1, \cdots, n), \\ 0 & (\mu = (2m-1)n + s; \\ & m = 1, \cdots, k; s = 1, \cdots, n), \end{cases} \quad (10)$$

则(1), (2)和(4)式中的 Λ_s 可表为

$$\tilde{f}_{\beta}^* (t, a^{\mu}) = 0 \quad (\mu = (2m-2)n + s; m = 1, \cdots, k; s = 1, \cdots, n), \quad (11)$$

$$\sum_{\mu=1}^{2nk} \frac{\partial \tilde{f}_{\beta}^*}{\partial a^{\mu+2n}} \delta a^{\mu} = 0, \delta t = 0,$$
$$\delta a^{\mu} \neq 0 \quad (\mu = (2m-2)n + s; m = 1, \cdots, k; s = 1, \cdots, n), \quad (12)$$

$$\tilde{\Lambda}_s^* = \sum_{\beta=1}^g \sum_{m=1}^k \lambda_{\beta}^m \frac{\partial \tilde{f}_{\beta}^*}{\partial a^{\mu+2n}} \quad (\mu = (2m-2)n + s;$$

$$m = 1, \cdots, k; s = 1, \cdots, n).$$
(13)

取

$$\tilde{\Lambda}_s = - \Omega_{s/m} \frac{\partial H}{\partial p_{s/m}}, \quad (14)$$

$$F_{\mu} = \begin{cases} \Omega_{s/m} \frac{\partial H}{\partial p_{s/m}} & (\mu = (2m-2)n + s; \\ & m = 1, \cdots, k; s = 1, \cdots, n), \\ 0 & (\mu = (2m-1)n + s; \\ & m = 1, \cdots, k; s = 1, \cdots, n), \end{cases} \quad (15)$$

正则方程(8)可进一步表示为协变代数方程

$$\left(\frac{\partial R_{\nu}}{\partial a^{\mu}} - \frac{\partial R_{\mu}}{\partial a^{\nu}} \right) \dot{a}^{\nu} - \frac{\partial H}{\partial a^{\mu}} = - F_{\mu} \quad (\mu, \nu = 1, \cdots, 2kn), \quad (16)$$

以及逆变代数方程

$$\dot{a}^{\mu} - s^{\mu\nu} \frac{\partial H}{\partial a^{\nu}} = 0 \quad (\mu, \nu = 1, \cdots, 2kn), \quad (17)$$

这里

$$s^{\mu\nu} = \omega^{\mu\nu} + T^{\mu\nu}, \quad (18)$$

其中

$$\omega^{\mu\nu} = \frac{\partial R_{\nu}}{\partial a^{\mu}} - \frac{\partial R_{\mu}}{\partial a^{\nu}},$$
$$(\omega_{\mu\nu}) = (\omega^{\mu\nu})^{-1}, \quad (19)$$

且

$$(\omega^{\mu\nu}) = \begin{bmatrix} M_1 & & \\ & \ddots & \\ & & M_k \end{bmatrix}_{2nk \times 2nk},$$

$$M_i = \begin{bmatrix} \mathbf{0}_{n \times n} & \mathbf{I}_{n \times n} \\ -\mathbf{I}_{n \times n} & \mathbf{0}_{n \times n} \end{bmatrix} \quad (i = 1, \cdots, k), \quad (20)$$

$$(T^{\mu\nu}) = \begin{bmatrix} \mathbf{0}_{n \times n} & & & & \\ & H_1 & & & \\ & & \ddots & & \\ & & & \mathbf{0}_{n \times n} & \\ & & & & H_i & \\ & & & & & \ddots \\ & & & & & & H_k \end{bmatrix}_{2nk \times 2nk},$$

$$H_i = \begin{bmatrix} \Omega_{1/m} & & & \\ & \Omega_{2/m} & & \\ & & \ddots & \\ & & & \Omega_{s/m} \end{bmatrix} \quad (i = m = 1, 2, \cdots, k; s = 1, 2, \cdots, n).$$
(21)

式中, $\mathbf{0}_{n \times n}$ 是 n 阶零矩阵, $\mathbf{I}_{n \times n}$ 是 n 阶单位矩阵. 设系统是非奇异的, 由方程(16)可解出 $\dot{a}^{\mu}$, 记作

$$\dot{a}^\mu = \tilde{\alpha}_\mu^*(t, \mathbf{a}) \quad (\mu = 1, \dots, 2nk). \quad (22)$$

3. 系统的确定方程和特殊 Lie 对称性

取时间不变的特殊无限小参数变换

$$t^* = t, a^{\mu*} = a^\mu + \varepsilon \xi_\mu(t, \mathbf{a}) \quad (\mu = 1, \dots, 2nk), \quad (23)$$

式中 ε 是无穷小参数, 具有一阶小量, ξ_μ 为无限小单参数变换的生成元, 引进无限小生成元向量及一次扩展

$$X^{(0)} = \xi_\mu \frac{\partial}{\partial a^\mu},$$

$$X^{(1)} = X^{(0)} + \dot{\xi}_\mu \frac{\partial}{\partial \dot{a}^\mu}, \quad (24)$$

根据微分方程在无限小变换下不变性的 Lie 理论, 广义线性非完整力学系统的不变性归结为如下确定方程:

$$X^{(1)}(\dot{a}^\mu - \tilde{\alpha}_\mu^*(t, \mathbf{a})) = 0 \quad (\mu, \nu = 1, \dots, 2nk), \quad (25)$$

展开(25)式, 得

$$\frac{\bar{d}}{dt} \xi_\mu = \xi_\nu \frac{\partial \tilde{\alpha}_\mu^*}{\partial a^\nu} \quad (\mu, \nu = 1, \dots, 2nk), \quad (26)$$

式中

$$\frac{\bar{d}}{dt} = \frac{\partial}{\partial t} + \tilde{\alpha}_\nu^* \frac{\partial}{\partial a^\nu}.$$

广义线性非完整约束(1)式在变换(23)式下的不变性归结为如下约束限制方程:

$$X^{(0)}[\bar{f}_\beta^*(t, \mathbf{a}^\mu)] = 0, \quad (27)$$

广义非完整力学的 Чераев 定义(2)式对虚位移 $\delta^{(m-1)} q_s$ 的限制归结为如下附加限制方程:

$$\frac{\partial \bar{f}_\beta^*}{\partial a^{\mu+2n}} \delta \xi_\mu = 0. \quad (28)$$

定义 1 如果无限小生成元 ξ_μ 满足确定方程(25), 则称相应的对称性为与广义线性非完整力学系统(1), (3)相应的广义完整力学系统(4)的特殊 Lie 对称性.

定义 2 如果无限小生成元 ξ_μ 满足确定方程(25)以及限制方程(27), 则称相应的对称性为广义线性非完整力学系统(1), (3)的特殊弱 Lie 对称性.

定义 3 如果无限小生成元 ξ_μ 满足确定方程(25)、限制方程(27)和附加限制方程(28), 则称相应的对称性为广义线性非完整力学系统(1), (3)的

特殊强 Lie 对称性.

4. 系统的 Hojman 守恒量

广义线性非完整力学系统的特殊 Lie 对称性直接导致 Hojman 守恒量的方法由下述定理给出.

命题 1 对于广义线性非完整力学系统(1), (3), 在无限小变换(23)下, 如果特殊 Lie 对称的、特殊弱 Lie 对称的或特殊强 Lie 对称的生成元 ξ_μ 满足确定方程(25), 且存在某函数 $\tilde{G}^* = \tilde{G}^*(t, \mathbf{a})$ 满足条件

$$\frac{\partial \tilde{\alpha}_\mu^*}{\partial a^\mu} + \frac{\bar{d}}{dt} \ln \tilde{G}^* = 0, \quad (29)$$

则广义线性非完整力学系统分别存在相应的广义完整力学系统 Hojman 守恒量, 以及广义线性非完整力学系统的弱 Hojman 守恒量或强 Hojman 守恒量, 形如

$$I_H = \frac{1}{\tilde{G}^*} \frac{\partial(\tilde{G}^* \xi_\mu)}{\partial a^\mu} = \text{常数}. \quad (30)$$

证明 利用定义 1—3、确定方程(23)和条件(29)可得(30)式.

利用命题 1, 立即得到一个重要推论.

命题 2 在无限小变换(23)下, 如果特殊 Lie 对称的、特殊弱 Lie 对称的或特殊强 Lie 对称的生成元 ξ_μ 满足确定方程(25), 且满足

$$\frac{\partial \tilde{\alpha}_\mu^*}{\partial a^\mu} = 0, \quad (31)$$

则广义线性非完整力学系统分别存在相应的广义完整力学系统 Hojman 守恒量, 以及广义线性非完整力学系统的弱 Hojman 守恒量或强 Hojman 守恒量, 形如

$$I_H = \frac{\partial \xi_\mu}{\partial a^\mu} = \text{常数}. \quad (32)$$

5. 算 例

设力学系统的广义 Lagrangian 为

$$L = \frac{1}{2} \dot{q}^2 + \frac{1}{2} \ddot{q}^2, \quad (33)$$

受线性非完整约束

$$f = \dot{q} - t\ddot{q} = 0, \quad (34)$$

试研究系统的 Lie 对称性与 Hojman 守恒量.

首先, 建立系统的运动方程. 由(5)和(6)式, 得

$$P_{1/1} = \frac{\partial L}{\partial \dot{q}} - \frac{d}{dt} \frac{\partial L}{\partial \ddot{q}} = \dot{q} - \ddot{q},$$
$$P_{1/2} = \frac{\partial L}{\partial \ddot{q}} = \ddot{q}, \tag{35}$$
$$H = P_{1/1} \dot{q} + P_{1/2} \ddot{q} - \frac{1}{2} \dot{q}^2 - \frac{1}{2} \ddot{q}^2. \tag{36}$$

由(7)式给出

$$\dot{q} = \frac{\partial H}{\partial P_{1/1}},$$
$$\dot{P}_{1/1} = -\frac{\partial H}{\partial q} + \Lambda^1 \frac{\partial \tilde{f}}{\partial \dot{q}}, \tag{37}$$
$$\ddot{q} = \frac{\partial H}{\partial P_{1/2}},$$
$$\dot{P}_{1/2} = -\frac{\partial H}{\partial \dot{q}} + \Lambda^1 \frac{\partial \tilde{f}}{\partial \dot{q}} + \Lambda^2 \frac{\partial \tilde{f}}{\partial \ddot{q}}, \tag{38}$$

其中 $\tilde{f} = \dot{q} - tP_{1/2} = 0$.

联合(35)—(38)式,求得

$$\Lambda_1^1 = P_{1/2}, \Lambda_1^2 = \frac{1}{t}(\dot{q} - P_{1/1} + P_{1/2}). \tag{39}$$

令

$$a^1 = q, a^2 = P_{1/1},$$
$$a^3 = \dot{q}, a^4 = P_{1/2},$$
$$R_1 = a^2, R_2 = 0,$$
$$R_3 = a^4, R_4 = 0, \tag{40}$$

则有

$$H = a^2 a^3 - \frac{1}{2}(a^3)^2 + \frac{1}{2}(a^4)^2, \tag{41}$$

$$F_1 = -a^4, F_2 = 0,$$
$$F_3 = -\frac{1}{t}(a^3 - a^2 + a^4), F_4 = 0. \tag{42}$$

据(18)—(21)式,得到

$$S^{\mu\nu} = \begin{pmatrix} 0 & 1 & 0 & 0 \\ -1 & -\frac{a^4}{a^3} & 0 & 0 \\ 0 & 0 & 0 & 1 \\ 0 & 0 & -1 & -\frac{a^3 - a^2 + a^4}{a^4 t} \end{pmatrix}, \tag{43}$$

由方程(17)给出系统的运动方程

$$\dot{a}^1 = a^3, \dot{a}^2 = -a^4,$$
$$\dot{a}^3 = a^4, \dot{a}^4 = \frac{(a^3 - a^2)(t - 1) - a^4}{t}. \tag{44}$$

其次,建立特殊 Lie 对称性的确定方程并求解. 确定方程(27)给出

$$\dot{\xi}_1 = \xi_3, \tag{45a}$$
$$\dot{\xi}_2 = -\xi_4, \tag{45b}$$
$$\dot{\xi}_3 = \xi_4, \tag{45c}$$
$$\dot{\xi}_4 = (\xi_3 - \xi_2)\left(1 - \frac{1}{t}\right) - \frac{\xi_4}{t}. \tag{45d}$$

方程(45)有如下解:

$$\xi_1 = 1, \xi_2 = \xi_3 = \xi_4 = 0, \tag{46}$$
$$\xi_1 = t, \xi_2 = \xi_3 = 1, \xi_4 = 0. \tag{47}$$

由约束限制方程(27)和附加限制方程(28)给出

$$\xi_3 - t\xi_4 = 0, \tag{48}$$
$$\xi_1 - t\xi_2 = 0. \tag{49}$$

容易验证,生成元(46)和(47)分别满足约束限制方程(48)和附加限制方程(49),但生成元(47)不满足约束限制方程(48),因此,生成元(46)和(47)为与广义线性非完整力学系统相应的完整系统的特殊 Lie 对称性,生成元(46)又是广义线性非完整力学系统的特殊弱 Lie 对称性.

最后求系统的守恒量. 由条件(29)得

$$-\frac{1}{t} + \frac{d}{dt} \ln \tilde{G}^* = 0, \tag{50}$$

有如下解:

$$\tilde{G}^* = t, \tag{51}$$
$$\tilde{G}^* = t(a^2 + a^3). \tag{52}$$

对于(46)和(51)式,(46)和(52)式以及(47)和(51)式,由(30)式得平凡的守恒量

$$I_1 = I_2 = I_3 = 0. \tag{53}$$

对于(47)和(52)式,由(30)式得非平凡的守恒量

$$I_4 = a^2 = \text{常数}. \tag{54}$$

6. 结 论

由于广义线性非完整力学系统包容了广义经典力学和一阶至高阶线性非完整力学,因此本文的主要结果(31)和(32)式具有普遍意义. 对于不受约束的力学系统,广义非完整约束力为 $\Lambda_s = 0$, 本文的结果与广义经典力学的结果相同^[18], 对于不受非完整约束的非保守力学系统,重新定义 Λ_s 为广义非势力, $\Lambda_s = Q_l \left(t, q_s, \dot{q}_s, \cdots, q_s^{(k)} \right)$, 则本文的研究结果蜕变为不受非完整约束的非保守广义力学系统 Hojman 守恒量的结果.

- [1] Mei F X 1999 *Applications of Lie Groups and Lie Algebras to Constrained Mechanical Systems* (Beijing: Science Press) (in Chinese) [梅凤翔 1999 李群和李代数对约束力学系统的应用(北京:科学出版社)]
- [2] Fang J H, Zhang P Y 2004 *Acta Phys. Sin.* **53** 4041 (in Chinese) [方建会、张鹏玉 2004 物理学报 **53** 4041]
- [3] Luo S K, Jin L Q, Cai J L 2005 *Commun. Theor. Phys.* **43** 193
- [4] Mei F X, Xu X J 2005 *Chin. Phys.* **14** 449
- [5] Xu X J, Qin M C, Mei F X 2005 *Chin. Phys.* **14** 1287
- [6] Hu H B 2005 *Chin. Phys.* **14** 452
- [7] Zhang Y 2008 *Acta Phys. Sin.* **57** 2643 (in Chinese) [张 毅 2008 物理学报 **57** 2643]
- [8] Lin P, Fang J H, Pang T 2008 *Chin. Phys.* **17** 4361
- [9] Ge W K 2008 *Acta Phys. Sin.* **57** 6714 (in Chinese) [葛伟宽 2008 物理学报 **57** 6714]
- [10] Hojman S A 1992 *J. Phys. A; Math. Gen.* **25** L291
- [11] Lutzky M 1995 *J. Phys. A; Math. Gen.* **28** L637
- [12] Mei F X 2002 *Chin. Sci. Bull.* **47** 1544
- [13] Mei F X 2003 *Acta Phys. Sin.* **52** 1046 (in Chinese) [梅凤翔 2003 物理学报 **52** 1046]
- [14] Zhang Y 2002 *Acta Phys. Sin.* **51** 461 (in Chinese) [张 毅 2002 物理学报 **51** 461]
- [15] Luo S K 2004 *Acta Phys. Sin.* **53** 666 (in Chinese) [罗绍凯 2004 物理学报 **53** 666]
- [16] Xu Z X 2002 *Acta Phys. Sin.* **51** 2423 (in Chinese) [许志新 2002 物理学报 **51** 2423]
- [17] Fang J H, Liao Y P, Zhang J 2004 *Acta Phys. Sin.* **53** 4037 (in Chinese) [方建会、廖永潘、张 军 2004 物理学报 **53** 4037]
- [18] Zhang Y 2003 *Acta Phys. Sin.* **52** 1832 (in Chinese) [张 毅 2003 物理学报 **52** 1832]
- [19] Luo S K 2002 *Acta Phys. Sin.* **51** 1416 (in Chinese) [罗绍凯 2002 物理学报 **51** 1416]
- [20] Judith G K, Joseph A S 1965 *Amer. J. Phys.* **33** 140
- [21] Zhang Y, Shang M, Mei F X 2000 *Chin. Phys.* **9** 401
- [22] Zhang Y 2001 *Acta Phys. Sin.* **50** 2059 (in Chinese) [张 毅 2001 物理学报 **50** 2059]

Hojman conserved quantities of generalized linear nonholonomic mechanical systems^{*}

Dong Wen-Shan^{1)†} Fang Jian-Hui²⁾ Huang Bao-Xin¹⁾

1) (Department of Physics and Electronic Science, Weifang University, Weifang 261061, China)

2) (Department of Applied Physics, University of Petroleum, Dongying 257061, China)

(Received 18 April 2009; revised manuscript received 19 May 2009)

Abstract

We study the Lie symmetries and Hojman conserved quantities of generalized linear nonholonomic mechanical systems. Under special infinitesimal transformations in which the time is invariable, the determining equations, the constrained restriction equations and the additional restriction equations of the nonholonomic mechanical systems are obtained. The Hojman conserved quantity of the corresponding holonomic systems, the weakly Hojman conserved quantity and the strongly Hojman conserved quantity of the linear nonholonomic systems are obtained. An example to illustrate the application of the result is given.

Keywords: generalized linear nonholonomic mechanical system, Lie symmetries, Hojman conserved quantity

PACC: 0320, 1110, 0220

^{*} Project supported by the Natural Science Foundation of Weifang University, China (Grant No. 2008Z03).

[†] E-mail: dongwenshan@126.com