YIRIK MASSHTABLI SISTEMALARNING DEKOMPOZITSIYASI

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Faraz qilaylik (S) yirik masshtabli sistemalar holati quyidagi differensial tenglama bilan ifodalansin.

$$\frac{dx}{dt} = f(t,x),$$

bu yerda $t \in T = (t_0, \infty) \subset R,\ x \in R^n,\ f \in F$ bo’lib , F oila quyidagicha aniqlanadi:

$F = \{f^1, f^2, \dots, f^N\},\ f^k: TxR^n \longrightarrow R^n,$

N- haqiqiy son.

Agar(S). Y.M.S. s ta qism sistemalaridan tashkil topgan bo’lsa , u holda (S) . Y.M.S. ni (S) o’zaro bog’liq bo’lgan qism sistemalaridan tashkiltopgan deb qarash mumkin bo’lib, (S) o’zaro bog’liq bo’lgan qism sistemalar quyidagi tenglamalar bilan ifodalanadi [1, 2, 3, 4, 5, 6, 7, 8, 9, 10]:

$$\frac{dx_i}{dt} = f_i(t,x), \qquad \forall\, i = 1,2,\dots,s$$

Bu yerda x va f vektorlar quyidagicha aniqlanadi:

$$x = (x_1^T, x_2^T, \dots, x_s^T)^T, \qquad f = (f_1^T, f_2^T, \dots, f_s^T)^T,$$

shuningdek,

$$f_i \in F_i,\quad F_i = (f_i^1, f_i^2, \dots, f_i^N),\quad f_i^k : TxR^n \longrightarrow R^{n_i},$$
$$\forall\, k = 1,2,\dots,N, \qquad n_1 + n_2 + \dots + n_s = n, \qquad i = 1,2,\dots,s.$$

f_i funksiyalar barcha $t \in R$ da, faqat va faqat x=0 dagina

f(t,x)=0

shartni qanoatlantiradi.

$$x^i = (O^T, O^T, \dots, x_i^T, O^T, \dots, O^T)^T, \qquad i = 1,2,\dots,s$$

belgilsh kiritamiz,

$g_i: TxR^{n_i} \longrightarrow R^{n_i},$

funksiyani

$$g_i(t,x_i) = f_i(t,x^i)$$

tenglik bilan aniqlaymiz.

U holda $(\widehat{S}_i)$ i- erkin qism sistema

$$\frac{dx_i}{dt} = g_i(t,x_i),$$

bu yerda $x_i \in R^{n_i}$,

$$f_i^*(t,x) = f_i(t,x) - g_i(t,x_i), \qquad \forall\, i = 1,2,\dots,s$$

Ifoda yordamida aniqlangan f_i^* funksiya (S) sistema o'zining (S_i) i -qism sistemasiga tasirini ifodalaydi.

(1.4) va (1.5) ga asosan (1.3) ni quyidagich yozish mumkin:

$$\frac{dx_i}{dt} = g_i(t, x_i) + f_i^*(t, x), \quad \forall\, i = 1,2, \dots, s$$

Agar

$$g = (g_1^T, g_2^T, \dots, g_s^T)^T, \qquad f^* = (f_1^{*^T}, f_2^{*^T}, \dots, f_s^{*^T})^T,$$

deb olsak, (1.6) ni quyidagicha yozish mumkin:

$$\frac{dx}{dt} = g(t, x) + f^*(t, x),$$

(S) Y.M.S. ni (1.6) ko'rinishda dekompozitsiya qilish zaruriy bo'lib , amaliy tadbiqlarda bu bir muncha noqulaydir. Masalan (1.5) tenglik yordamida f funksiyalarni har doim ham aniqlash ham qulay bo'lavermaydi. Shuning uchun (S) Y.M.S. ni dekompozitsiya qilishni qulaylashtirish maqsadida har bir s ta (S) qism sistemalardan iborat bo'lgan Y.M.S bilan sxs tartibli matritsa o'rtasida quyidagicha o'zaro bir qiymatli mosli o'rnatamiz [11, 12, 13, 14, 15, 16]:

1. (S) Y.M.S.ning $(\widehat{S}_i)$ erkin qism sistemalarini matritsaning bosh dioganaliga mos qo'yamiz;

2. $(\widehat{S}_i)$ qism sistemalarni $(\widehat{S}_j)$ qism sistemaga ta'sirini ifodalovchi funksiyani i-satr va j-ustun kesishgan joyga mos qo'yamiz. Natijada matrirsaning bosh dioganalida erkin qism sistemalar bo'lib, bosh dioganaldan tashqarida bu erkin qism sistemalar orasidagi to'g'ri va teskari bog'lanishlar bo'ladi.

Bunday moslik o'rnatilgandan keyin (1.1) sistema quyidagi ko'rinishlarning biriga keladi:

$$\frac{dx}{dt} = Ax,$$

$$\frac{dx}{dt} = A(t)x,$$

$$\frac{dx}{dt} = A(x),$$

$$\frac{dx}{dt} = A(t, x),$$

bu yerda A, A(t), A(x), A(t,x)-bosh dioganalga nisbatan simmetrik bo'lgan sxs tartibli kvadrat matritsalar.

Sistemalarning dekompozitsiya qilish masalasi mos ravisha blok matritsalarga ajratish masalasi bilan teng kuchli bolgan uchun dekompozitsiya qilish masalasi matritsani blok matritsalarga ajratish masalasiga keladi.

Misol tariqasida (1.8) sistemani ba'zi xusussiy xollarda dekompozitsiya qilish usullarini qarab chiqamiz.Faraz qilaylik,A matritsa markazga nisbatan simmetrik bolgan sxs olchovli kvadrat matrirsa bolsin. U holda (1.8) sistemani quyidagicha usullarda dekompozitsiya qilish mumkin [17, 18, 19, 20, 21, 22]:

1.Vertikal va gorizantal simmetriya oqlariga nisbatan dekompozitsiya qilish.

Bu holda (1.8) sistema n=2k da,

$$\dot{y} = A_1 y + B_1 z,$$
$$\dot{z} = B_1^0 y + A_1^0 z,$$

korinishiga, n=2k+1 da esa

$$\dot{y} = A_1 y + a_2 x_{k+1} + B_1 z,$$
$$\dot{x}_{k+1} = a_1^T y + a_{k+1,k+1} x_{k+1} + (a_1^T)^0 z$$
$$\dot{z} = B_1^0 y + a_2^0 x_{k+1} + A_1^0 z,$$

korinishga keladi. Bu yerda erkin qism sistemalar

$$\dot{y} = A_1 y,$$
$$\dot{z} = A_1^0 y,$$
$$\dot{x}_{k+1} = a_{k+1,k+1} x_{k+1}$$

korinishida bolib, A_1, B_1- k-tarkibli kvadrat matritsalar, A_1^0, B_1^0 mos ravishda ularni markazga nisbatan transponirlangani [21],vektorlar esa

$$a_1 = \left(a_{k+1}, a_{k+1,2}, \dots, a_{k+1,k}\right)^T, \qquad a_2 = \left(a_{k+1,k+2}, a_{k+1,k+3}, \dots, a_{k+1,n}\right)^T,$$
$$y = (x_1, x_2, \dots, x_k)^T, \qquad y = (x_{k+2}, x_{k+3}, \dots, x_n)^T, \qquad x = (y^T, x_{k+1}, z^T)^T.$$

korinishida aniqlangan.

(1.8) sistema muvozanat holati turg’unligining yetarli shartlarini hosil qilish uchun (1.12) bolgan sistema va (1.14), (1.15) qism sistemalarga mos lyapunov matritsa funksiyasi quyidagi korinishda tanlanadi [23, 24, 25, 26, 27, 28, 29, 30]:

$$U_1(y,z) = \begin{pmatrix} v_{11}(y) & v_{12}(y,z) \\ v_{21}(y,z) & v_{22}(z) \end{pmatrix}, \qquad v_{12} = v_{21},$$

bu yerda

$$v_{11}(y) = y^T P_1 y, \qquad v_{22}(z) = z^T P_1^0 z, \qquad v_{12}(y,z) = v_{21}(y,z) = y^T P_2 z$$

P_1, P_1^0 - bosh dioganalga nisbatan simmetrik bolgan musbat aniqlangan matritsalar,

P_2 - ozgarmas matritsa bolib, ularning barchasi k-tarkibli matritsalardir.

(1.13) sistema va (1.14),(1.15),(1.16) qisim sistemalariga mos Lyapunov matritsa funksiyasi esa,quydagicha tanlanadi.

$$U_2(y, x_{k+1}, z) = \left(v'_{ij}\right), \qquad i,j = 1,2,3, \qquad v'_{ij} = v'_{ji}$$

bu yerda

$$v'_{11} = v'_{11}(y), \quad v'_{12} = a_{12} x_{k+1} y, \quad v'_{13} = v_{12}(y,z) \quad v'_{21} = v'_{12}, \quad v'_{22} = a_{22} x_{k+1}^2,$$
$$v'_{23} = a_{23} x_{k+1} z, \quad v'_{33} = v_{22}(z), \quad v'_{31} = v'_{13}, \quad v'_{32} = v'_{23}$$

P_1, P_1^0, P_2 - matritsalar(1.17) dagidek aniqlanadi, $\alpha_{22} > 0$, α_{12}, α_{23} lar haqiqiy sonlar.

2.O‘zaro muvozanatchi qisim sistemalariganisbatan dekompozitsiya qilish. Bu holda n=2k da

$$\dot{y}_i = A_{ii} y_i + \sum_{\substack{j=1 \\ i \neq j}}^{k} A_{ij} y_j\,, \qquad i = 1,2,\dots,k = \frac{n}{2}$$

ko’rinishiga, n=2k+1 da esa,

$$\dot{y}_i = A_{ii}y_i + \sum_{\substack{j=1 \\ i\neq j}}^{k} A_{ij}y_j + a_i x_{k+1}, \qquad i = 1,2,\dots,k = \frac{n-1}{2},$$

$$\dot{x}_{k+1} = a_{k+1,k+1}x_{k+1} + \sum_{i=1}^{k} a_i\,, y_i,$$

ko'rinishga keladi. Bu yerda

$$A_{ii} = \begin{pmatrix} a_{ii} & a_{i,n+1-i} \\ a_{i,n+1-i} & a_{ii} \end{pmatrix}, \qquad A_{ij} = \begin{pmatrix} a_{ij} & a_{i,n+1-j} \\ a_{i,n+1-j} & a_{ij} \end{pmatrix},$$

$$a_i = \left(a_{i,k+1}, a_{i,k+1}\right)^T, \qquad a_j = \left(a_{k+1,j}, a_{k+1,j}\right)^T,$$

$$y_i = (x_i, x_{n+1-i})^T, \qquad y = (y_1^T, y_2^T, \dots, y_k^T)^T, i,j = 1,2,\dots,k, \quad i \neq j,$$

Bo'lib, A_{ii} va A_{ij} lar matritsa markaziga nisbatan simmetrik bo'lgan matritsalardir [31, 32, 33, 34].

Bu holatda i-erkin sistemalar

$$\dot{y}_i = A_{ii}y_i$$

korinisgida bo'lib, ularning muvozanat holati turgunligini yetarli shartlari

$$a_{ii} < 0, \quad |a_{ii}| > |a_{i,n+1-i}|, \quad i = 1,2,\dots,k$$

shartlaridan,

$$\dot{x}_{k+1} = a_{k+1,k+1}x_{k+1}$$

qisim sistema uchun muvozanat holat turgunliging yetarli sharti

$$a_{k+1,k+1} < 0\ .$$

dan iborat boladi.(1.19)va (1.20)sistemalar hamda(1.21),(1.23) qism sistemalar uchun yuqoridagi kabi Lyapunov matritsa funksiyalarini tuzish mumkin [35, 36, 37, 38].

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