Adaptive Control of Systems with Actuator Failures
(**G. Tao, S. H. Chen, X. D. Tang and S. M. Joshi**, Springer, 2004; ISBN 1-85233-788-5)

Corrections, Remarks and References

- On page 22, (2.31) defines a set of m_0+1 functions V_p for all m_0+1 failure patterns σ (including $\sigma=0$ for the no-failure pattern), and their matching parameters k^*_{1j}, k^*_{2j} and k^*_{3j} are fixed at the values $k^*_{1j(i)}$, $k^*_{2j(i)}$ and $k^*_{3j(i)}$, for all $t\geq 0$, e.g., for the first function V_0 (the no failure case), k^*_{1j}, k^*_{2j} and k^*_{3j} are $k^*_{1j(0)}$, $k^*_{2j(0)}$ and $k^*_{3j(0)}$, for all $t\geq 0$; for the next function V_1 (if one failure occurred) or V_2 (if two failures occurred) or V_3 (if three failures occurred), k^*_{1j}, k^*_{2j} and k^*_{3j} are $k^*_{1j(1)}$, $k^*_{2j(1)}$ and $k^*_{3j(1)}$, for all $t\geq 0$; and so on.

  With this definition, the functions V_p are continuous functions for all $t\geq 0$.

- On page 24, line 4, "It can also be verified" should be "If $\dot{r}(t)$ is also bounded, then it can be verified".

- On page 25, in (2.46), "$(k_{3i}(t)-k^*_{3i(0)})$" should be "$(k_{3i}(t)-k^*_{3i(0)})^2$", and in (2.47), "$(k_{3i}(t)-k^*_{3i(1)})$" should be "$(k_{3i}(t)-k^*_{3i(1)})^2$".

- On page 72, (3.73) should be
$$\alpha_{ij}=c\bar{A}^{n^*-1}b_j.$$

- **Remark**: On pages 71 and 72, the proof of Lemma 3.2.1, for the case when $c\bar{A}^{n^*-1}b_i=\alpha_{ii}\neq 1$, can also be obtained with the following minor changes:

$$c(sI-\bar{A})^{-1}b_iP_m(s)=\alpha_{ii} \tag{64}$$

$$c(sI-\bar{A})^{-1}b_i=\frac{s^{n-n^*}+c_{n-n^*}s^{n-n^*-1}+\cdots+c_2s+c_1}{s^n+a_ns^{n-1}+\cdots+a_2s+a_1}\alpha_{ii} \tag{67}$$

$$c\bar{A}^kb_i=\frac{\alpha_{ii}}{\alpha_{ij}}c\bar{A}^kb_j=0,\ k=0,1,\ldots,n^*-2 \tag{72}$$

$$\alpha_{ij}=c\bar{A}^{n^*-1}b_j \tag{73}$$

$$c\bar{A}^{n^*-1}b_i=\frac{\alpha_{ii}}{\alpha_{ij}}c\bar{A}^{n^*-1}b_j \tag{74}$$

$$c\bar{A}^kb_i=\frac{\alpha_{ii}}{\alpha_{ij}}c\bar{A}^kb_j \tag{75}$$

$$c\bar{A}^k(b_i-\frac{\alpha_{ii}}{\alpha_{ij}}b_j)=0,k=0,1,\ldots,n-1 \tag{76}$$

Using this result and applying (3.60)) to $c(sI-\bar{A})^{-1}(b_i-\frac{\alpha_{ii}}{\alpha_{ij}}b_j)$, we obtain

$$c(sI-\bar{A})^{-1}\left(b_i-\frac{\alpha_{ii}}{\alpha_{ij}}b_j\right)=0. \tag{77}$$

In view of (3.58), we see that (3.77) is equivalent to (3.59): $c(sI-A-b_ik^{*T}_{1i})^{-1}b_j=\alpha_{ij}W_m(s)$. This result is true for all $j=1,2,\ldots,m,\ j\neq i$.

- **Remark**: On pages 71 and 72, the proof ot Lemma 3.2.1 is given based on a controllable canonical form realization (A, b_i, c) and the fact that (A, b_i, c) and (A, b_j, c) have the same relative degree n^*. The result of the lemma leads to

$$c(sI - A - b_i k_{1i}^{*T})^{-1}[b_i f_i + b_j u_j](t) = W_m(s)\alpha_{ii}[f_i](t) + W_m(s)\alpha_{ij}[u_j](t)$$

for two signals $f_i(t)$ and $u_j(t)$, as $c(sI - A - b_i k_{1i}^{*T})^{-1} b_i = W_m(s)\alpha_{ii}$ and $c(sI - A - b_i k_{1i}^{*T})^{-1} b_j = W_m(s)\alpha_{ij}$, for $\alpha_{ii} = c(A + b_i k_{1i}^{*T})^{n^*-1} b_i$ and $\alpha_{ij} = c(A + b_i k_{1i}^{*T})^{n^*-1} b_j$ as verified in the proof.

When (A, b_i, c) is not in the controllable canonical form realization but (A, b_i, c) and (A, b_j, c) have the same relative degree n^*, there is a transformation matrix T such that $A_c = T^{-1}AT$, $b_{ic} = T^{-1} b_i$ and $c_c = cT$ are in in the controllable canonical form realization, so that

$$\begin{aligned} & c(sI - A - b_i k_{1i}^{*T})^{-1}[b_i f_i + b_j u_j](t) \\ = & c_c(sI - A_c - b_{ic} k_{1ic}^{*T})^{-1}[b_{ic} f_i + T^{-1} b_j u_j](t), \end{aligned}$$

where $k_{1ic}^{*T} = k_{1i}^{*T} T$. Since ($A_c$, b_{ic}, c_c) and (A_c, $T^{-1}b_j$, c_c) have the same relative degree and (A_c, b_{ic}, c_c) is the controllable canonical form realization, we also have

$$c(sI - A - b_i k_{1i}^{*T})^{-1}[b_i f_i + b_j u_j](t) = W_m(s)\alpha_{ii}[f_i](t) + W_m(s)\alpha_{ij}[u_j](t).$$

- **Remark**: From Lemma 3.2.1, we can see that

$$c(sI - A - b_i k_{1i}^{*T})^{-1} b_i = \frac{1}{k_{2i}^* P_m(s)} = -c(sI - A - b_i k_{1i}^{*T})^{-1} b_j \frac{1}{k_{3i}^*}$$

have the same zeros. This can be verified as follows. From $c(sI - A - b_i k_{1i}^{*T})^{-1} b_i = \frac{1}{k_{2i}^* P_m(s)}$, it follows that there are $n - n^*$ poles of $\bar{A} = A + b_i k_{1i}^{*T}$ (those different from the zeros of $P_m(s)$) are made unobservable by k_{1i}^* at $y(t) = cx(t)$ (that is, (c, $A + b_i k_{1i}^{*T}$) has $n - n^*$ unobservable poles), given that ($A + b_i k_{1i}^{*T}$, b_i) is controllable as (A, b_i) is controllable and the state feedback gain k_{1i}^* does change the controllability of ($A + b_i k_{1i}^{*T}$, b_i) and (A, b_i). This implies that

$$c(sI - A - b_i k_{1i}^{*T})^{-1} b_j = \frac{P_j(s)}{P_m(s)}$$

for some polynomial $P_j(s)$ of degree $n^* - 1$ or less.

From the condition that $cA^k b_i = 0$, $cA^k b_j = 0$, $k = 0, 1, \ldots, n^* - 2$, we have

$$c\bar{A}^k b_j = c(A + b_i k_{1i}^{*T})(A + b_i k_{1i}^{*T})^{k-1} b_j = cA(A + b_i k_{1i}^{*T})^{k-1} b_j = \cdots = cA^k b_j = 0$$

for $k = 0, 1, \ldots, n^* - 2$, and from the additional condition that $cA^{n^*-1} b_j \neq 0$, that

$$c\bar{A}^{n^*-1} b_j = cA(A + b_i k_{1i}^{*T})^{n^*-2} b_j = \cdots = c(A^{n^*-1} + A^{n^*-2} b_i k_{1i}^{*T}) b_j = cA^{n^*-1} b_j \neq 0.$$

From (3.60)–(3.62), the degree of $N(s)$ for $b = b_j$ is $n - n^*$, that is, the degree of $P_j(s)$ is 0.

This remark actually gives a simpler proof of Lemma 3.2.1.

The case when the degree of $P_j(s)$ is larger than 0 corresponds to the case when the relative degree of (A, b_j, c) is less than n^*, that is, when $c\bar{A}^k b_j \neq 0$ for some $k < n^* - 1$.

What if the relative degree of (A, b_j, c) is larger than n^*, e.g., $cA^{n^*-1}b_j = 0$ in addition, so that

$$c\bar{A}^{n^*-1}b_j = cA(A+b_ik_{1i}^{*T})^{n^*-2}b_j = \cdots = c(A^{n^*-1}+A^{n^*-2}b_ik_{1i}^{*T})b_j = cA^{n^*-1}b_j = 0,$$

in addition to $c\bar{A}^kb_j = c(A+b_ik_{1i}^{*T})^kb_j = 0$ for $k = 0,1,\ldots,n^*-2$. In this case, it follows from (3.69): $c(\bar{A}^{n^*}+a_{n^*}^*\bar{A}^{n^*-1}+a_{n^*-1}^*\bar{A}^{n^*-2}+\cdots+a_2^*\bar{A}+a_1^*I) = 0$, that $c\bar{A}^{n^*}b_j = 0$. Similarly, $c\bar{A}^kb_j = 0$ for $k = n^*+1,\ldots,n-1$, so that $N(s) = 0$ in (3.62) with $b = b_j$, that is, $P_j(s) = 0$ or $c(sI-A-b_ik_{1i}^{*T})^{-1}b_j = 0$. Thus, we have the result:

Proposition 1 *Assume that (A,b_i) is controllable and there are $k_{1i}^* \in R^n$ and $k_{2i}^* \in R$ such that*

$$c(sI-A-b_ik_{1i}^{*T})^{-1}b_ik_{2i}^* = W_m(s) = \frac{1}{P_m(s)}$$

where $P_m(s)$ is a monic polynomial of degree n^*. Then, (i) for any $b_j \in R^n$ such that the relative degree of (c, A, b_j) is $n_1^* < n^*$, there is a polynomial $P_j(s)$ of degree $n^*-n_1^*$ such that

$$c(sI-A-b_ik_{1i}^{*T})^{-1}b_j = \frac{P_j(s)}{P_m(s)};$$

and (ii) for any $b_j \in R^n$ such the relative degree of (c, A, b_j) is $n_2^* > n^*$, it follows that

$$c(sI-A-b_ik_{1i}^{*T})^{-1}b_j = \frac{0}{P_m(s)} = 0.$$

Note that $c\bar{A}^{n^*}b_j = 0$ means that

$$c\bar{A}^{n^*}b_j = cA(A+b_ik_{1i}^{*T})^{n^*-1}b_j = \cdots = c(A^{n^*}+A^{n^*-1}b_ik_{1i}^{*T})b_j = cA^{n^*}b_j + cA^{n^*-1}b_ik_{1i}^{*T}b_j = 0.$$

A direct proof of $cA^{n^*}b_j + cA^{n^*-1}b_ik_{1i}^{*T}b_j = 0$ may not be simple.

- On page 72, after (3.75), "$k = n*$ to $k = n-1$" should be "$k = n^*$ to $k = n-1$".
- On page 78, (3.112) should be
$$f_i^*(t) = \sum_{j\neq i} -\frac{\alpha_{ij}}{\alpha_{ii}}u_j(t).$$
- On page 79, the last sentence of the paragraph above (3.113) is so stated for the problem of "up to $m-1$" actuator failures, which implies that (c,A,b_j), $j = 1,2,\ldots,m$, all have relative degree n^*, a condition needed for the matching equation (3.116) (the corrected version; see below).

  For the problem of totally less than $m-1$ actuator failures, the condition that (c,A,b_j), $j = 1,2,\ldots,m$, all have relative degree n^* needs to be explicitly stated.
- On page 80, (3.116) should be

$$c\left(sI-A-\sum_{j\neq j_1,\ldots,j_p} b_jk_{11}^{*T}\right)^{-1}\left[\sum_{j\neq j_1,\ldots,j_p} b_jf_1^* + \sum_{j=j_1,\ldots,j_p} b_ju_j\right](t) = 0.$$

- **Remark**: In this equation, $\bar{A} \stackrel{\triangle}{=} A + \sum_{j \neq j_1,\ldots,j_p} b_i k_{11}^{*T}$ is the nominal closed-loop system characteristic matrix for a desired nominal value k_{11}^* of the gain vector k_{11}, such that

$$c\left(sI - A - \sum_{j\neq j_1,\ldots,j_p} b_j k_{11}^{*T}\right)^{-1} \sum_{j\neq j_1,\ldots,j_p} b_j = W_m(s) k_{21}^{*-1}$$

(by the closed-loop plant-model matching condition) and

$$c\left(sI - A - \sum_{j\neq j_1,\ldots,j_p} b_j k_{11}^{*T}\right)^{-1} b_j = -W_m(s) k_{3j}^* k_{21}^{*-1}$$

(by Lemma 3.2.1), where

$$k_{3j}^* = -\frac{\alpha_{ij}}{\alpha_{ii}},\ k_{21}^* = \frac{1}{\alpha_{ii}}$$

$\alpha_{ij} = c\bar{A}^{n^*-1} b_j$ and $\alpha_{ii} = c\bar{A}^{n^*-1} \sum_{j\neq j_1,\ldots,j_p} b_j$ (as from the proof of Lemma 3.2.1).

The controller (3.113) can then be expressed as

$$v_1(t) = v_2(t) = \cdots = v_m(t) = \theta^T \omega$$

for some parameter vector θ which contains all parameters of k_{11}, k_{21} and those in $f_1(t)$, and a corresponding vector signal $\omega(t)$. The same form of the error equation (3.101) can be obtained with the new notation $\bar{A} = A + \sum_{j\neq j_1,\ldots,j_p} b_i k_{11}^{*T}$ and $\rho^* = 1/k_{21}^*$.

- **Remark**: For (3.47), with the designs of Chapter 3, if the relative degree of (A, b_i, c) is equal to the relative degree of (A, b_j, c), then u_i can compensate (reject) a time-varying failure $u_j = \bar{u}_j(t)$; if the relative degree of (A, b_i, c) is less than the relative degree of (A, b_j, c), then u_i can make the effect of u_j disappear (using state feedback, which is crucial); and if the relative degree of (A, b_i, c) is larger than the relative degree of (A, b_j, c), then u_i can only compensate (reject) a constant failure $u_j = \bar{u}_j = \bar{u}_{j0}$.

  The equal relative degree assumption (A3.2) is needed for the considered problem in which there can be up to $m-1$ actuator failures in the system, including the case when mutural failure compensation of actuators is needed, that is, (A, b_i, c) and (A, b_j, c) have to have the same relative degree, in order for them to be able to compensate for each other's failure.

- **Remark**: If the relative degree of (A, b_i, c) is larger than the relative degree of (A, b_j, c), then u_j can compensate (reject) a time-varying failure $u_i = \bar{u}_i(t)$ (it can make the effect of u_i disappear by using state feedback). An input filter at u_j can make the relative degree of the new (A, b_j, c) equal to that of (A, b_i, c) but this does not help the new u_j to deal with u_i (while u_j can still compensate (reject) a time-varying failure $u_i = \bar{u}_i(t)$ but it no longer can make the effect of u_i disappear using state feedback, so it actually decreases the compensation power of the new u_j). Morever, when u_j fails it fails at the old u_j, and u_i still can only compensate (reject) a constant failure $u_j = \bar{u}_j = \bar{u}_{j0}$. Hence, the idea of using an input filter does not relax any failure compensation condition.

- **Remark**: For (4.55), if the relative degree of $\frac{Z_i(s)}{P(s)}$ is equal to the relative degree of $\frac{Z_j(s)}{P(s)}$, then u_i can compensate (reject) a time-varying failure $u_j = \bar{u}_j(t)$, if the relative degree of $\frac{Z_i(s)}{P(s)}$ is less than the relative degree of $\frac{Z_j(s)}{P(s)}$, then u_i can compensate (reject) a time-varying failure $u_j = \bar{u}_j(t)$ but cannot make the effect of u_j disappear by using output feedback (see page 99), and if the relative degree of $\frac{Z_i(s)}{P(s)}$ is larger than the relative degree of $\frac{Z_j(s)}{P(s)}$, then u_i can only compensate (reject) a constant failure $u_j = \bar{u}_j = \bar{u}_{j0}$.

Similarly, the equal relative degree assumption in (A4.1) is needed for the considered problem in which there can be up to $m-1$ actuator failures in the system, including the case when mutual failure compensation of actuators is needed.

- On page 98, line 7, "$\theta_1^{*T}\omega_1(t)$" should be "$\theta_1^{*T}\frac{a(s)}{\Lambda(s)}$".
- On page 98, line 10, "(3.7)" should be "(3.47)".
- On page 98, line 14, "tracking" should be "tracks".
- **Remark**: On page 46, for the conditions (2.166)–(2.168), if they hold for $q = 1$, then they also hold for $m > q \geq 1$. In other words, if any $m-q$ failures can be compensated, then any $m-i$ failures can be compensated for every $i = q+1, q+2, \ldots, m-1$ (and $i = m$, the no failure case).
- **Remark**: On page 99, line 5, $P_i(s)$ is a monic polynomial of degree n^*-1, satisfies $\frac{\Lambda(s)P_m(s)}{P(s)} = P_i(s) + \frac{R(s)}{P(s)}$ for some polynomial $R(s)$ of degree $n-1$ (such that $\theta_1^{*T}a(s) + \theta_{20}^*\Lambda(s) = -\theta_3^* R(s)$).
- On page 99 and page 100, use the notation "ϕ_j^*" to replace "θ_j^*" in (4.65), (4.66) and (4.70), and "$\psi_j(t)$" to replace "$\omega_j(t)$" in (4.65), (4.66), (4.69), (4.70), (4.71) and (4.73).
- On page 100, in (4.70), "$A(s)$" is revised as

$$A(s) = [I_{q+1}, sI_{q+1}, \ldots, s^{n-2}I_{q+1}]^T.$$

- On page 101, use the notation "ϕ_j^*" to replace "θ_j^*" in line 8, (4.78) and θ_{60}^* ($\phi_1^*, \ldots, \phi_m^*$), "$\psi_j(t)$" to replace "$\omega_j(t)$" in line 8, (4.80) ($\psi_1(t), \ldots, \psi_m(t)$), and "$\omega_{60}(t)$" to replace "$\bar{\omega}(t)$".
- On page 101, "$\omega_6(t)$" in (4.80) is revised as

$$\omega_6(t) = [(\frac{A(s)}{\Lambda(s)}[\psi_1](t))^T, \ldots, (\frac{A(s)}{\Lambda(s)}[\psi_m](t))^T]^T.$$

- On page 101, "$A(s)$" in (4.80) is revised as

$$A(s) = [I_{q+1}, sI_{q+1}, \ldots, s^{n-2}I_{q+1}]^T.$$

- **Remark**: On page 102, after "...$\lim_{t\to\infty}(y(t) - y_m(t)) = 0$", we note the following:

  In the parametrization (4.79), the parameter vector dimensions can be reduced. For θ_{60}^*, since the first components of $\omega_i(t)$ (which is $\psi_i(t)$, under the new notation), $i = 1, 2, \ldots, m$, are all equal to 1, the corresponding components in θ_{60}^* can be combined as one single parameter, with the first components of $\omega_i(t)$ (or $\psi_i(t)$), $i = 2, \ldots, m$, being deleted from $\bar{\omega}(t)$ (which is $\omega_{60}(t)$, under the new notation).

Similarly, for θ_6^* and $\omega_6(t)$, the first components of $\frac{A(s)}{\Lambda(s)}[\psi_i](t)$, $i = 1, 2, \ldots, m$, are all the same (which converges to the constant $\frac{1}{\Lambda(0)}$ and can be replaced by $\frac{1}{\Lambda(0)}$ in the design), and the corresponding components in θ_6^* can be combined as one single parameter, with the first components of $\frac{A(s)}{\Lambda(s)}[\psi_i](t)$, $i = 2, \ldots, m$, being deleted from $\omega_6(t)$. The $(k(q+1)+1)$th components of $\frac{A(s)}{\Lambda(s)}[\psi_i](t)$, $i = 1, 2, \ldots, m$, are all the same (equal to 0), for $k = 1, \ldots, n-2$, which can be deleted from $\omega_6(t)$, with the corresponding components in θ_6^* being also deleted from θ_6^*.

In the expression (4.53), a more compact form is with $q = q_j$ for each j, which can be similarly handled with a modification to the parametrization (4.79).

- On page 105, line 3, "$G_{ij}(s)$, $i = 1, \ldots, M$, $j = 1, \ldots, n_i$, are $1 \times M$ vectors" should be "$G_{ij}(s)$, $i = 1, \ldots, M$, $j = 1, \ldots, n_i$, are $M \times 1$ vectors".

- On page 119, in (5.81) and (5.82), "-0.12879" should be "-0.012879" and "0.21326" should be "0.021326".

- On page 120, in (5.83), "-0.12879" should be "-0.012879" and "-0.13" should be "-0.013".

- On page 155, in line 5, change "We segment the elevator into" to "For (7.40), we segment the elevator into", and in (7.61), change "$B = [b_2, b_3]$" to "$B = [b_1, b_2]$".

- On page 156, in line 14, change "$v(t)$" to "$v(t) = v_0(t)$".

- On page 120, in the line before (5.85), change "no-failure case" to "no-failure case with (5.82)".

- On page 173, in equation (8.68), "$0 < \gamma_\theta < \frac{1}{k_p^0}$" should be "$0 < \gamma_\theta < 1$".

- On page 174, equation (8.68) should be

$$\sum_{t=t_1}^{t_2} (y(t) - y_m(t))^2 \leq c_1 + c_2 \sum_{t=t_1}^{t_2} d^2(t) + c_3 \mu^2 (t_2 - t_1)$$

- On page 182, in (9.18) and (9.20), u_1 should be "$P\xi + S\eta + c_{n-\rho} u_1$"; below (9.18), add "$P \in R^{1\times\rho}$ and $S \in R^{1\times(n-\rho)}$ are some vectors" and in (9.19), T_2 should be:

$$T_2 = \begin{bmatrix} c_c \\ c_c A_c \\ \vdots \\ c_c A_c^{\rho-1} \\ P \end{bmatrix}.$$

- **Remark**: On page 226, in (10.141), and after, the same notation "θ" is used to denote an unknown parameter vector, instead of the bitch angle in (10.138) until before (10.141).

- On page 258, line 16, and, on page 261, the last line, "Remark 11.5.1" should be "Remark 11.4.3"

- The example in Chapter 11, Section 11.4.4, is from

  H. Xu and M. Mirmirani, "Robust adaptive sliding control for a class of MIMO nonlinear systems," *Proceedings of the 2001 AIAA Guidance, Navigation and Control Conference*, Montreal, Canada, August 2001.

  with the altitude fixed as a constant so that the system become a SISO one.

- On page 265, last line, "7–11" should be "7–8".

- **Remark**: On page 266, the aircraft models are studied in different chapters:

  - Boeing 737 longitudinal dynamics model (elevator/stabilizer failure)
    Chapter 7
  - Boeing 737 lateral-directional dynamics model (rudder/aileron failure)
    Chapter 5
  - Boeing 747 lateral-directional dynamics model (rudder failure)
    Chapter 2, Chapter 3, Chapter 4, Chapter 8
  - DC-8 lateral-directional dynamics model (aileron failure)
    Chapter 6
  - F-18 wing dynamics model (aileron failure)
    Chapter 10
  - Twin Otter longitudinal nonlinear dynamics model (elevator failure)
    Chapter 10
  - a hypersonic aircraft longitudinal nonlinear model (elevator failure).
    Chapter 11

References of Our Recent Related Work

Journal Papers

[1] X. D. Tang, G. Tao, L. F. Wang and J. A. Stankovic, "Robust and adaptive actuator failure compensation designs for a rocket fairing structural-acoustic model," *IEEE Transactions on Aerospace and Electronic Systems*, vol. 40, no. 4, pp. 1359–1366, October 2004.

[2] X. D. Tang, G. Tao and S. M. Joshi, "Adaptive output feedback actuator failure compensation for a class of nonlinear systems," *International Journal of Adaptive Control and Signal Processing*, vol. 19, pp. 419–444, 2005.

[3] X. D. Tang, G. Tao and S. M. Joshi, "Virtual grouping based adaptive actuator failure compensation for MIMO nonlinear systems," *IEEE Transactions on Automatic Control*, vol. 50, no. 11, pp. 1775–1780, 2005.

[4] X. D. Tang, G. Tao and S. M. Joshi, "Adaptive actuator failure compensation for nonlinear MIMO systems with an aircraft control application," acceptable for *Automatica*.

Conference Papers

[1] X. D. Tang and G. Tao, "Adaptive compensation of actuator failures for nonlinear MIMO systems under relaxed design conditions," *Proceedings of the 2003 American Control Conference*, pp. 5123–5128, Denver, CO, June 2003.

[2] L. F. Wang, X. T. Tang, G. Tao and J. A. Stankovic, "Actuator failure compensation schemes for vibration control of a rocket fairing model," *Proceedings of the 5th IFAC Symposium on Fault Detection, Supervision and Safety of Technical Processes*, pp. 175–180, Washington, D.C., June, 2003.

[3] E. F. Kececi, X. D. Tang and G. Tao, "Adaptive actuator failure compensation for concurrently actuated manipulators," *Proceedings of the 5th IFAC Symposium on Fault Detection, Supervision and Safety of Technical Processes*, pp. 411–416, Washington, DC, June 2003.

[4] E. F. Kececi, X. D. Tang and G. Tao, "Adaptive actuator failure compensation for cooperating multiple manipulator systems," *Proceedings of the 5th IFAC Symposium on Fault Detection, Supervision and Safety of Technical Processes*, pp. 417–422, Washington, DC, June 2003.

[5] J. T. Fei, S. H. Chen, G. Tao and S. M. Joshi, "A discrete-time adaptive actuator failure compensation controller," *Proceedings of the 5th IFAC Symposium on Fault Detection, Supervision and Safety of Technical Processes*, pp. 423–428, Washington, DC, June 2003.

[6] X. D. Tang, G. Tao and S. M. Joshi, "Adaptive output feedback actuator failure compensation for a class of state-dependent nonlinear systems," *Proceedings of the 42nd IEEE Conference on Decision and Control*, pp. 1681–1686, Maui, Hawaii, 2003.

[7] X. D. Tang, G. Tao and S. M. Joshi, "Adaptive output feedback design for actuator failure compensation using dynamic bounding: output tracking and an application," *Proceedings of the 2005 American Control Conference*, pp. 3186–3191, Portland, Oregon, 2005.

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