

Using geometric moments to explain human letter recognition near the acuity limit

Lei Liu


Stanley A. Klein

Feng Xue



Jun-Yun Zhang

Cong Yu



 



 



 



 

Journal of Vision, 9(1):26, 1-18, http://journalofvision.org/9/1/26/, doi:10.1167/9.1.26.

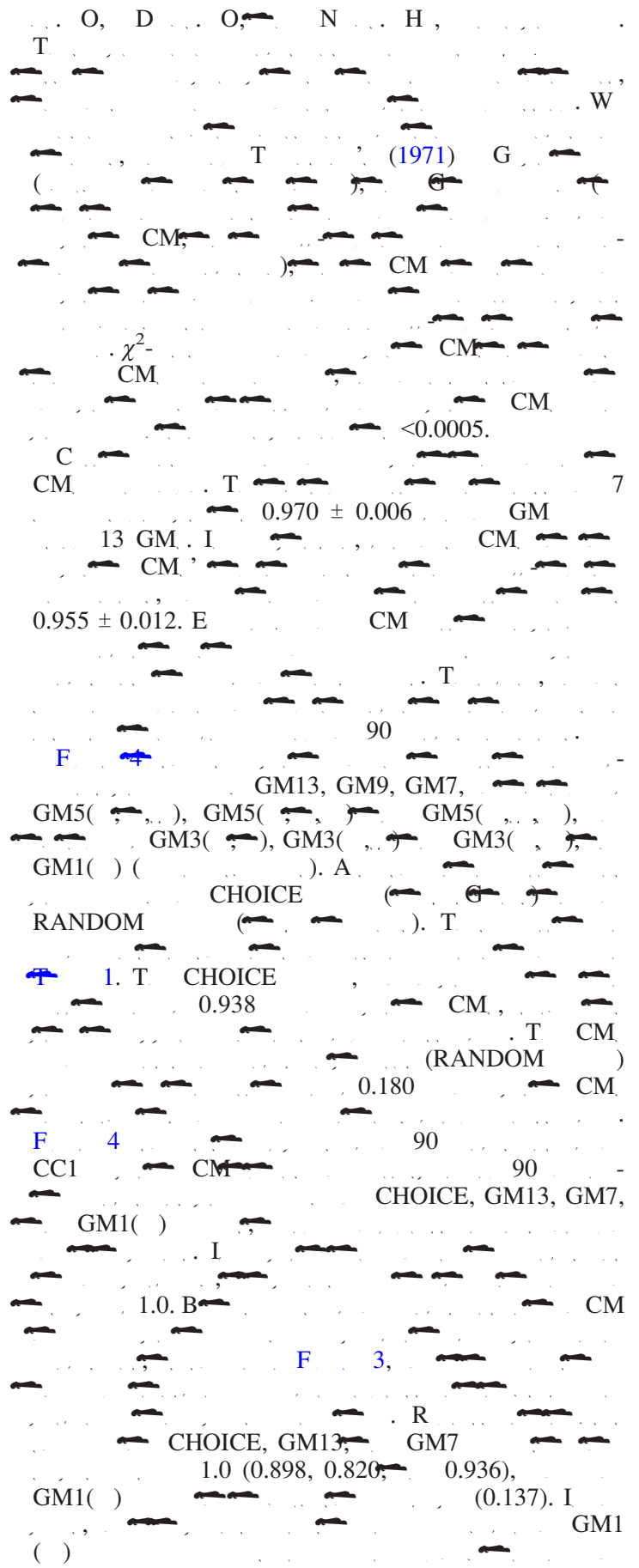
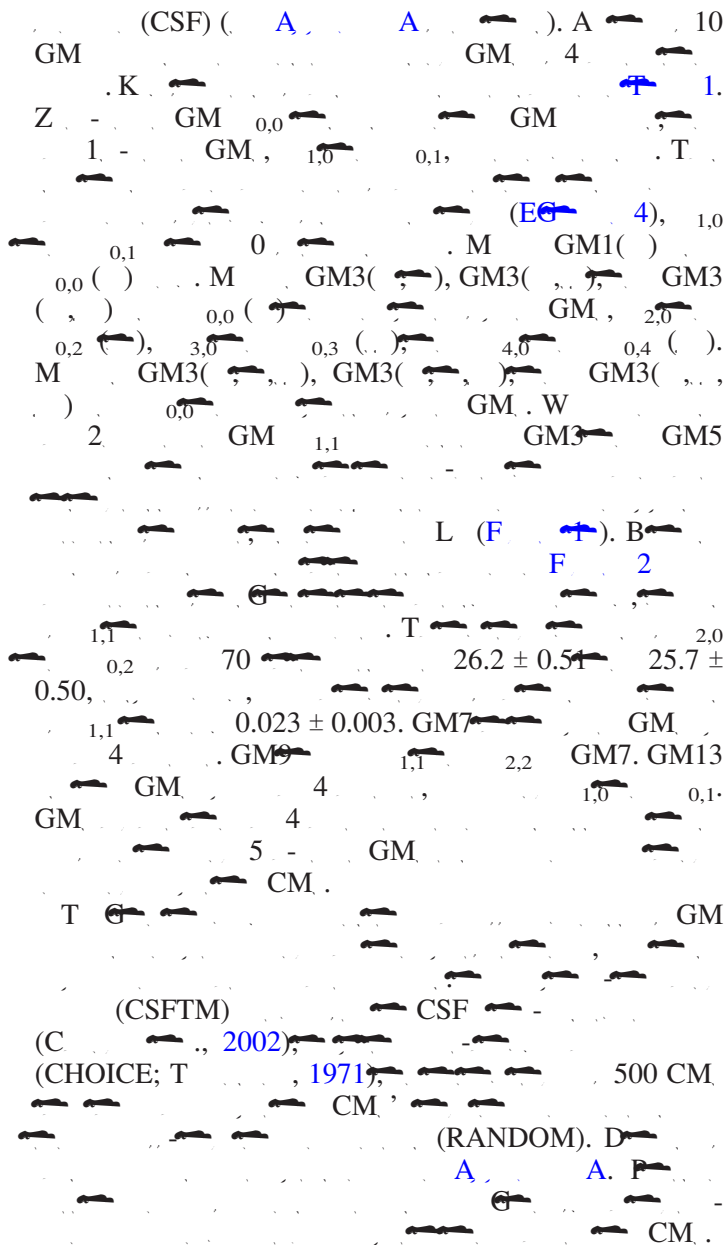
Introduction

V... W... C (I... (ISO), 1986; N... (NAS-NRC), 1980), I... US, ETDRS (F... B... & B... 1982), 10... E... (S...). S... T... H... ?... I... G... R... /

(1 2) G (1 2 /) (G... 1977; & S... 1991; S... & P... 1994). B... D... (1997) F... E... S... E... 1.4 1.7 / T... G... T... (1997) F... G... B... C

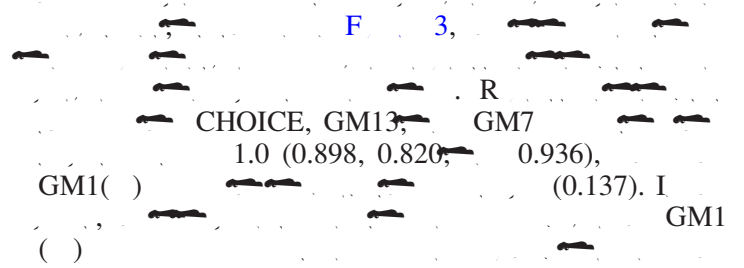
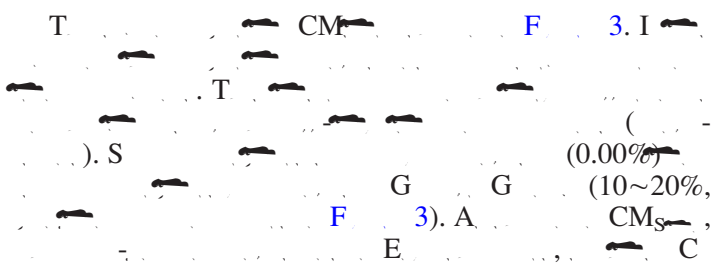


T
 I
 T 2 - 2,0 0,2
 EG 5 1.0. B /
 0,2 σ_x σ EG 3. W 3
 (4,0 0,4)
 EG 5
 x-
 T GM
 F GM
 2-D F GM ((x,) = 0 1)
 F 0 GM
 I F
 0,0
 P 2 - ()
 0-) 2,0 0,2
 F F
 (/ = 5/1), 2,0 < 0,2 (2.872 ... 14.431). F
 , 2,0 > 2,0 (14.431 ... 2.872). I
 GM
 G
 GM (F



Results

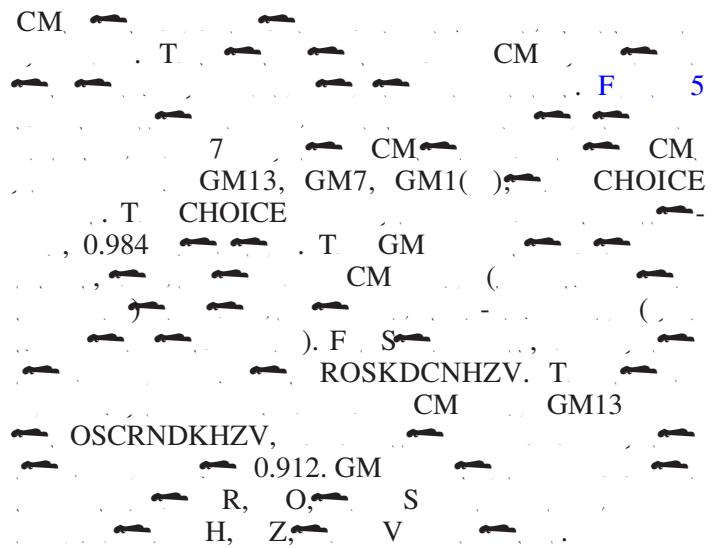
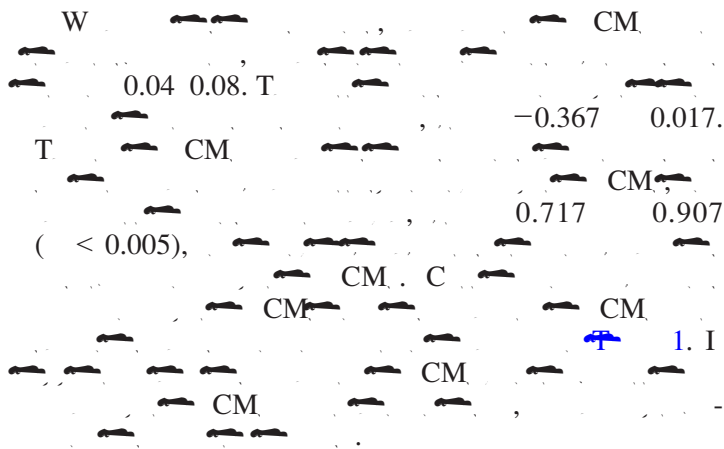
Using GM models to predict human confusions



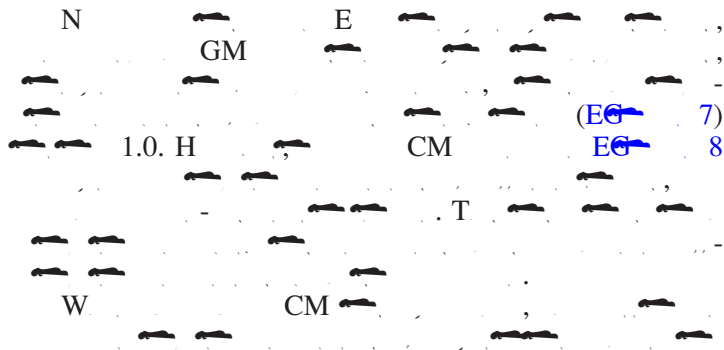
C
C 0.57
D 0.0

電感數路德增解
需
題路德增解就其覽

CHOICE₂ 0.163, 0.484, GM13, CHOICE CC5 0.476 0.595, F RANDOM CM₅ 7 S
GM GM GM1() W 7 GM, 0.362 0.770. W 13 GM

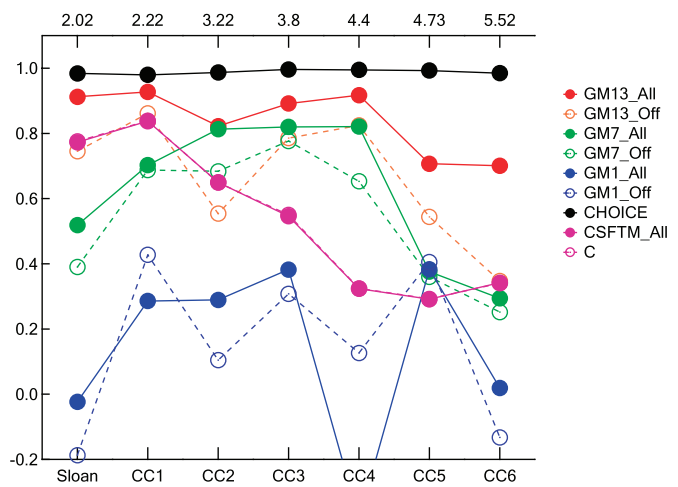
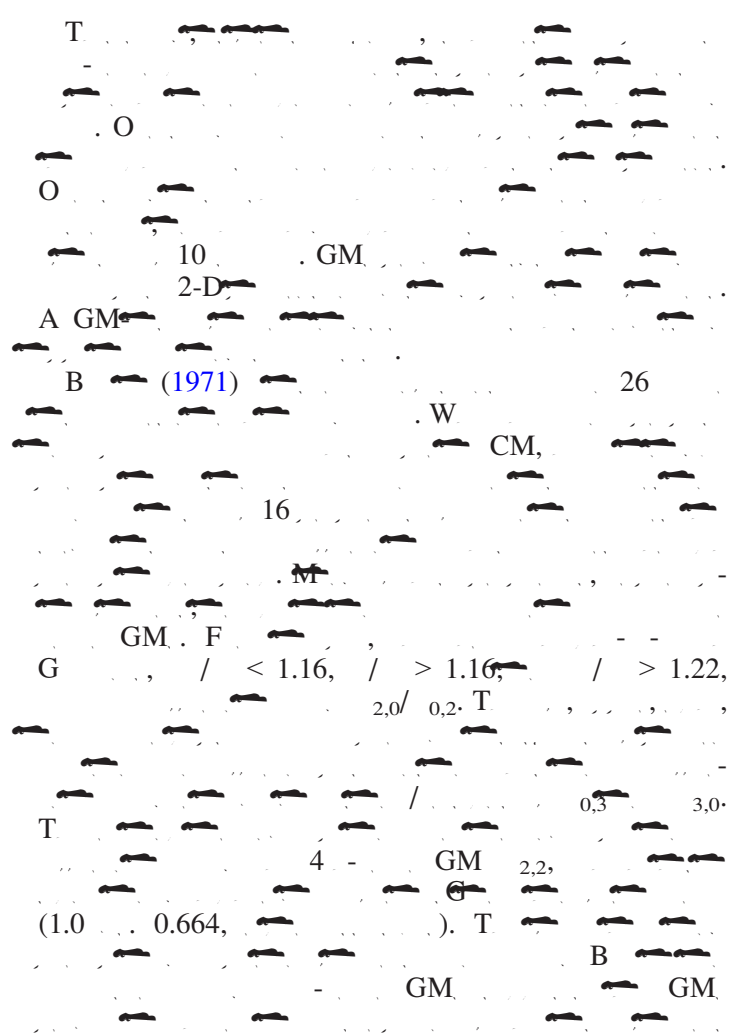


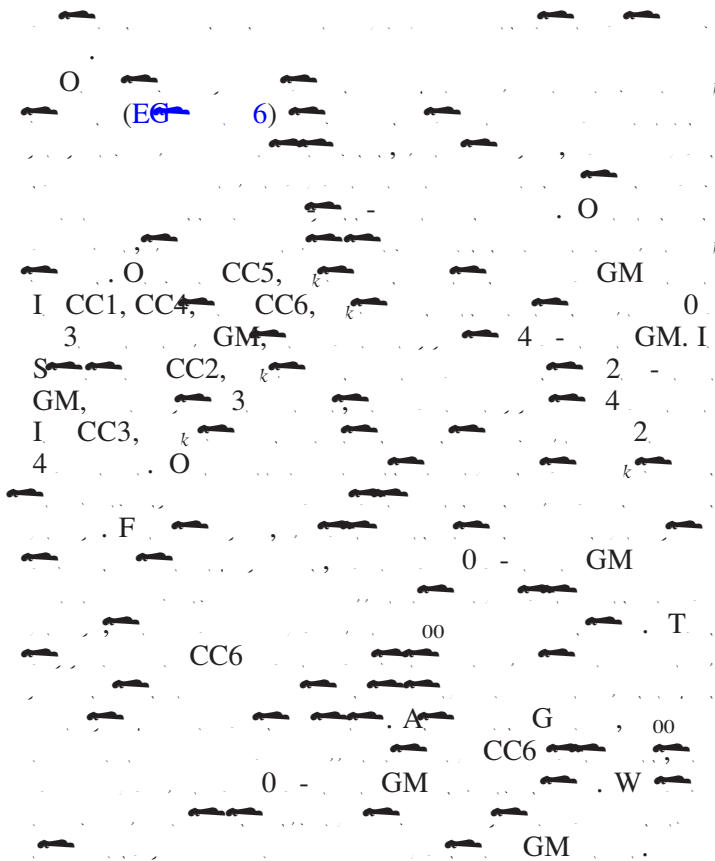
Relative legibility



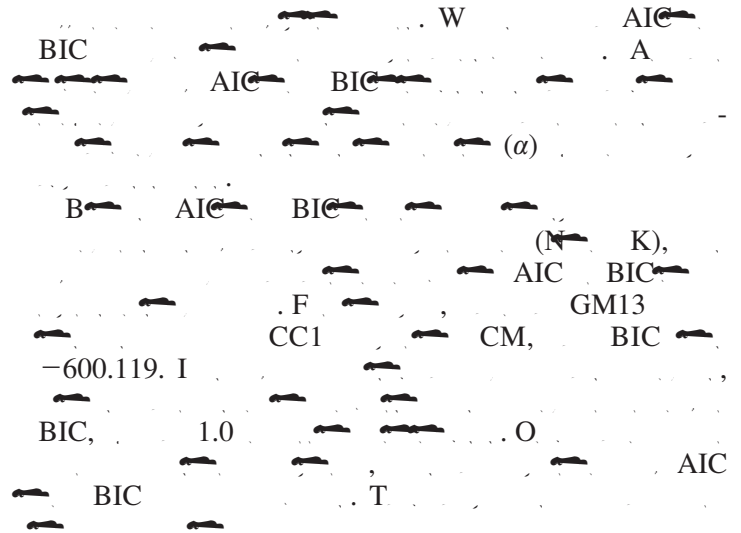
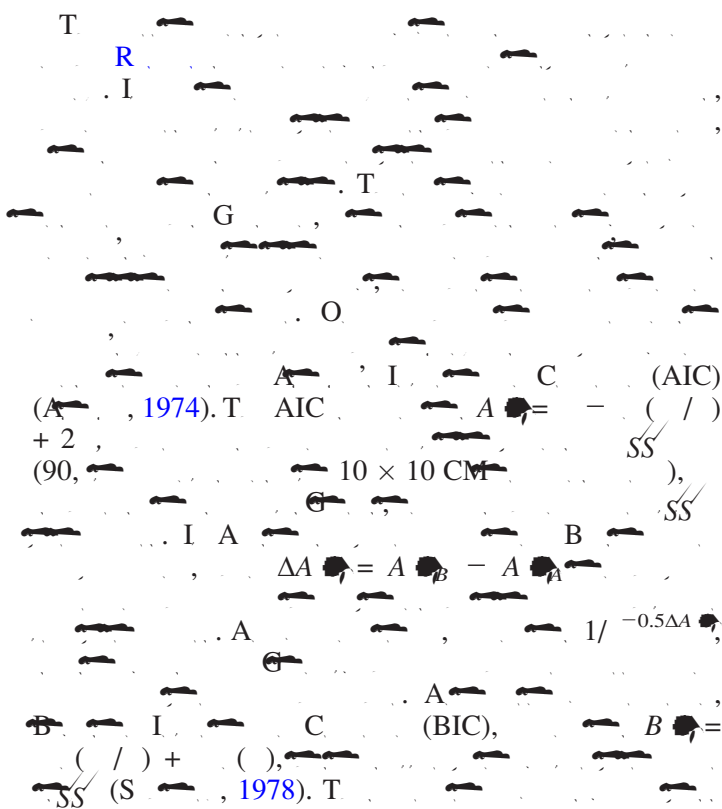
Discussion

GM as visual features

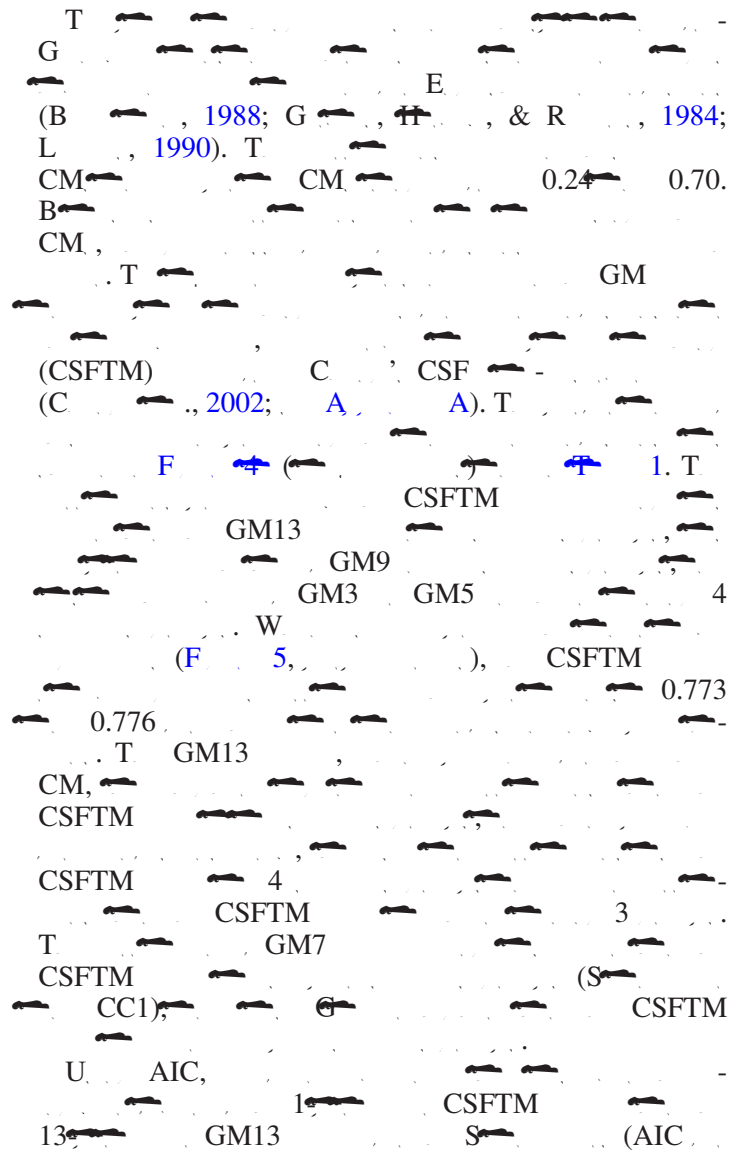




Models with different number of parameters



Template matching vs. Feature analysis



GM13 CSFTM -590.061 -607.049, 4886.27). H
 GM13 5 6 CC CC5 GM13
 (> 2280)
 (2.05). C CSFTM
 GM9 W CSFTM
 GM I
 54 CHOICE CSFTM CHOICE S
 (3.84),
 CHOICE (> 2 × 10¹¹).
 U BIC, CSFTM GM13
 S CC2, CC5, CC6
 CC1, CC3, CC4 W GM13 CSFTM
 CHOICE BIC, CSF
 T CSFTM S
 1 CSFTM I
 CC1 CC3, GM13 GM9 CSFTM
 CSFTM I
 T CSFTM CSF. W CSFTM
 (). T
 CSF ANOVA, 2,12 = 1.179, = 0.341).

70 (7 × 10
 GM) (2,120 =
 0.182, = 0.893) *
 0.419, = 0.982). T (18,120 =
 GM
 T
 GM T
 W
 T
 I GM T
 GM T

Relative legibility, response bias, and asymmetry of confusion matrices

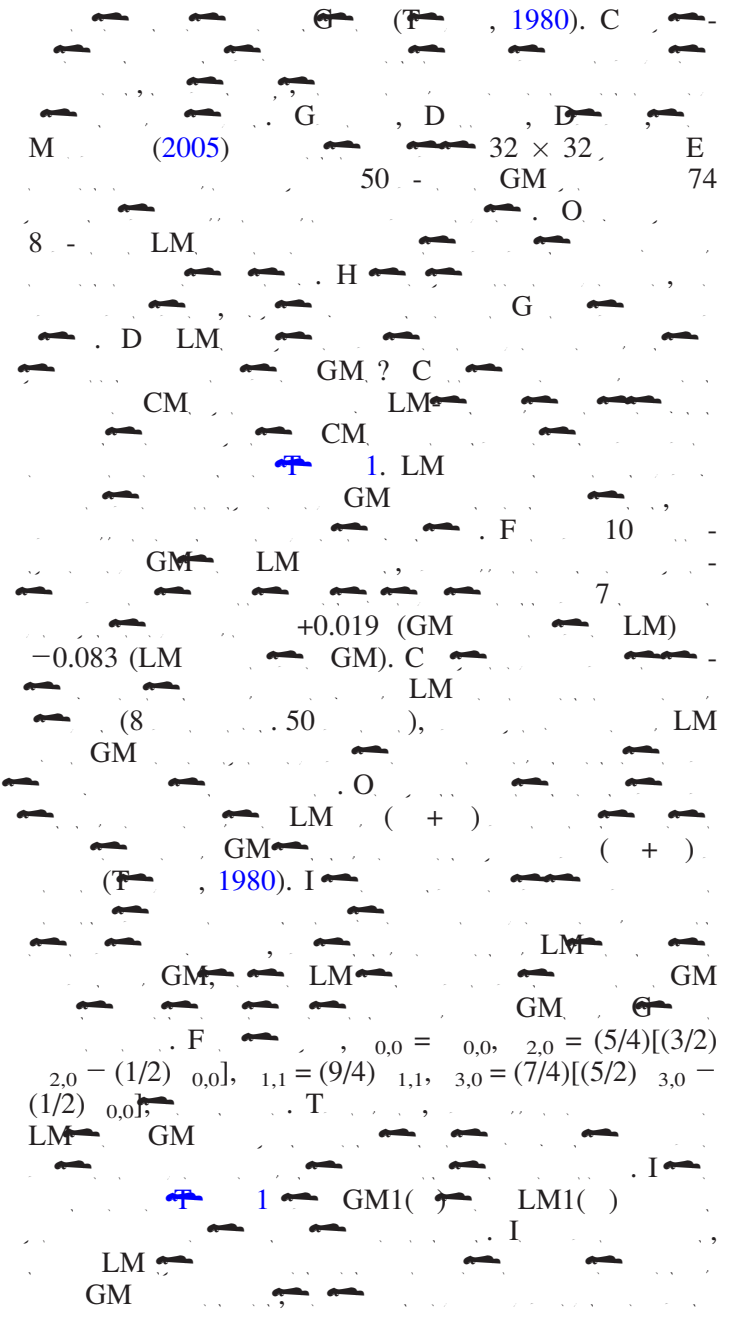
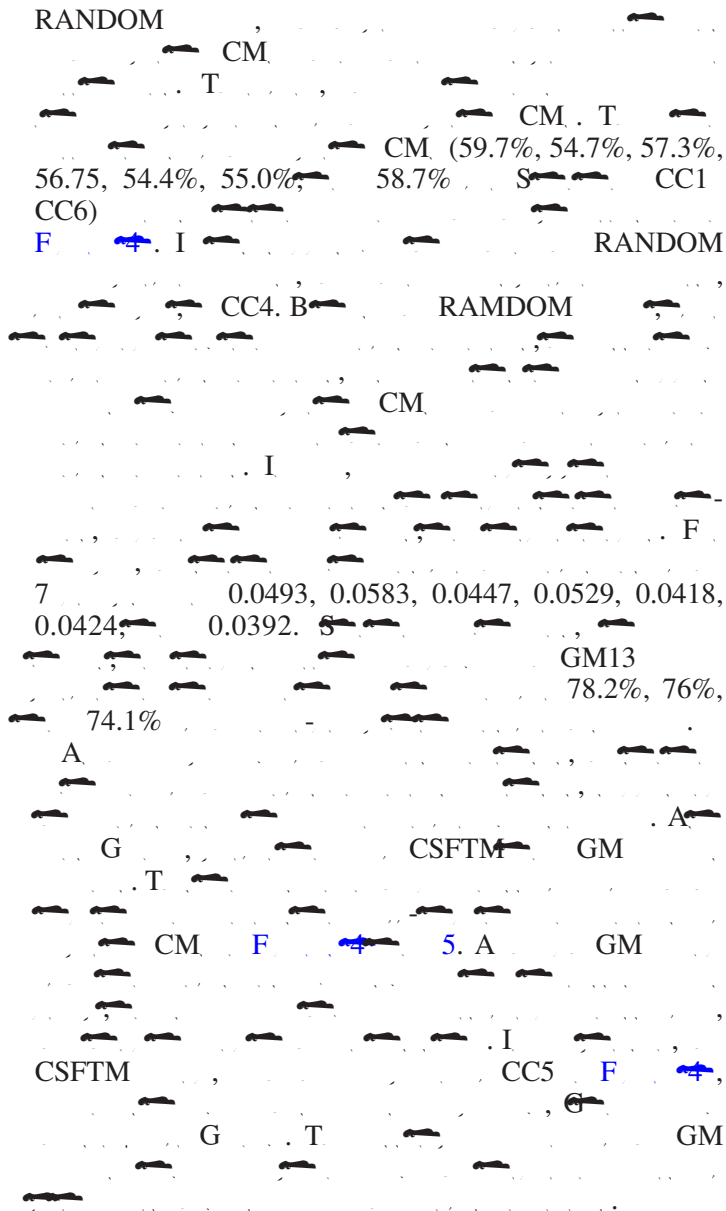
W CM
 (T, 1971), G
 I CMs
 H R (75%
 38%). T
 R 0.012 R H
 H R 0.123. I
 CM, T CM

Inter-group variations

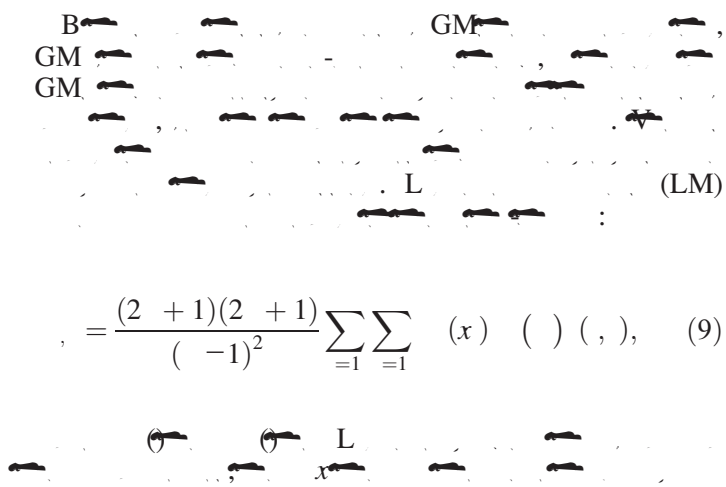
I F GM
 S CC1, CC3, CC5 CC2, CC4,
 CC6. I A CHOICE
 GM CM T

The effect of the front-end filter

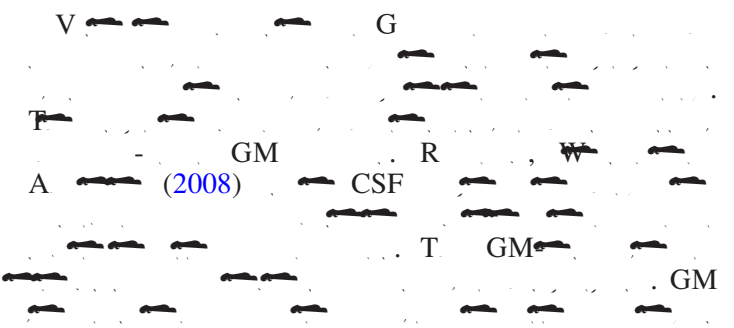
I CSF
 T GM
 GM CSF
 (ZJY CSF, 3.8-
 F A+), G (1966; CG PSF).
 T ZJY CSF, CLT CSF, G T CG PSF
 (G, 1984)
 CLT CSF, ZJY CSF, CG PSF
 A ANOVA



Non-orthogonal GMs vs. orthogonal moments



Visual acuity and beyond



T M
W GM
H
4 8 F
(L, P, R
& S, 1985; P, 1962), 15
E (L, H, K, S, M, C, &
F, 2002; L, 1985; R & M C,
1976). W
(≈ 3.4)
S
I
G
T
F
E & S, 1978; L, 1979; S, 1991;
T, H, & K, 1988). W
(L, 1979; S, 1991),
T
E & S, 1978; L, 1979; S, 1991).
A

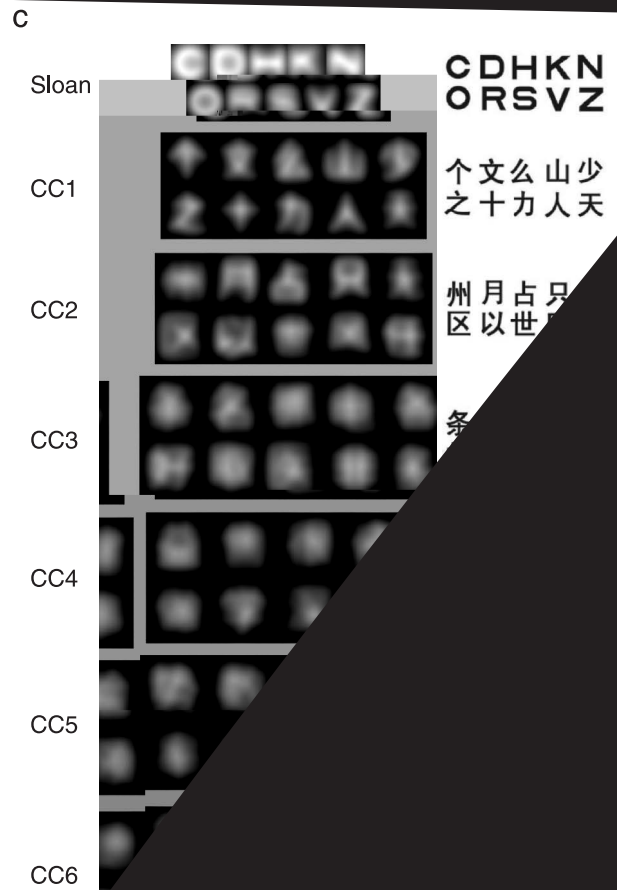
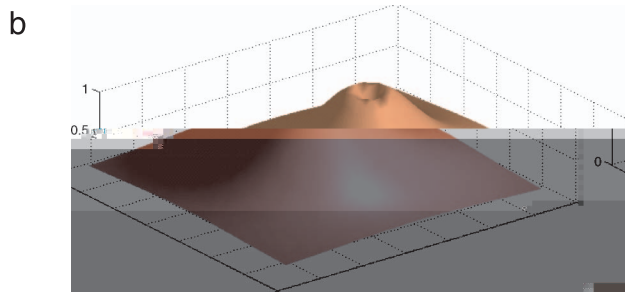
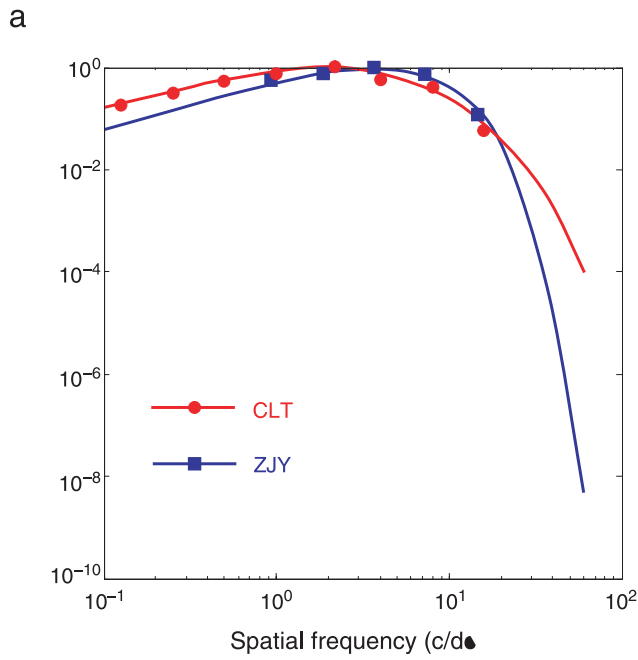
I (B, 1988; (CSF)
L, 1990) (C, 2002)
W CSF
GM CSF S C (M &
(2002; F 2). A 3 (M &
S, 1974)
 $S(\cdot) = -(\cdot)$, (A1)
CSF. T
= 812.3, $b = 1.071$, $\sigma = 0.636$. T C, L
F (CLT) CSF F A1
A 2-D F A1
G T F A1
S C F 2.
A 50 x 50 B
0.1
700 / S 398 /
CC6. T F F
F CLT CSF F
T F A1 T
1.2x C 3x
P
GM EG 2.5 CM +1
EG 6.8. A
CM O
CM I
50% 75%, I
CM
G (L B & M, 1985).
I CM
T F 2. 0.1

Appendix A: Models and their implementations

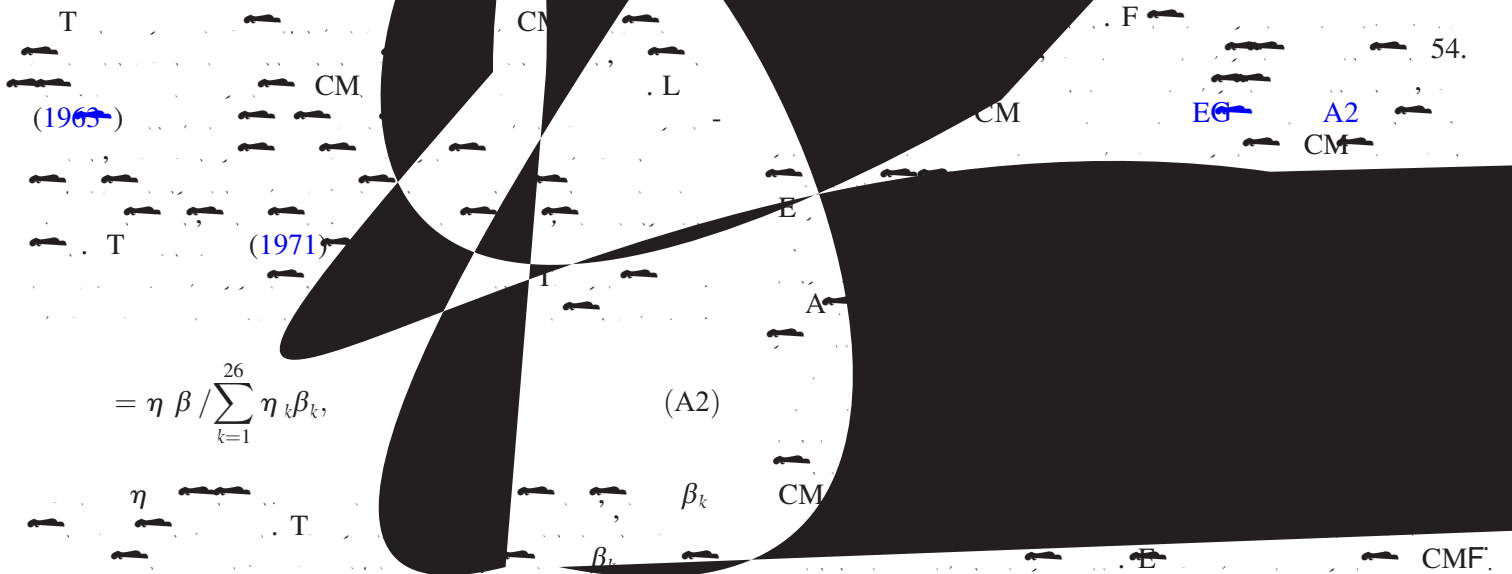
Implementation of GM models

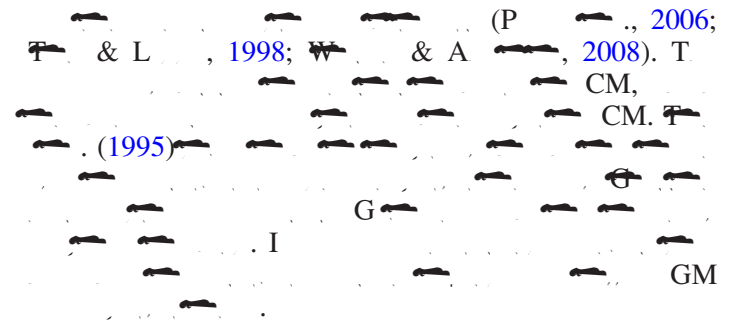
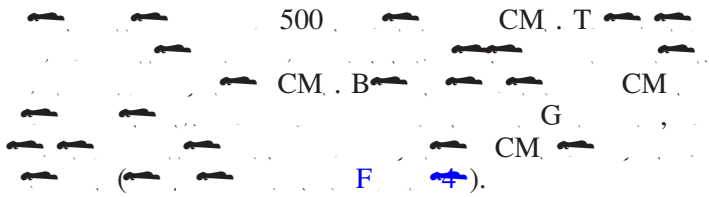
B GM

T F 2. 0.1

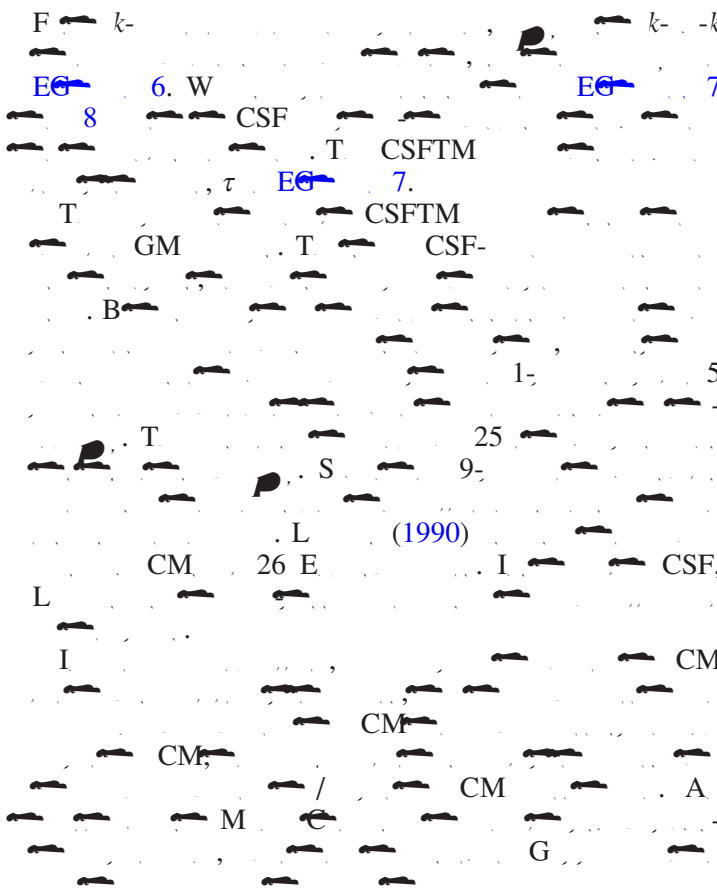
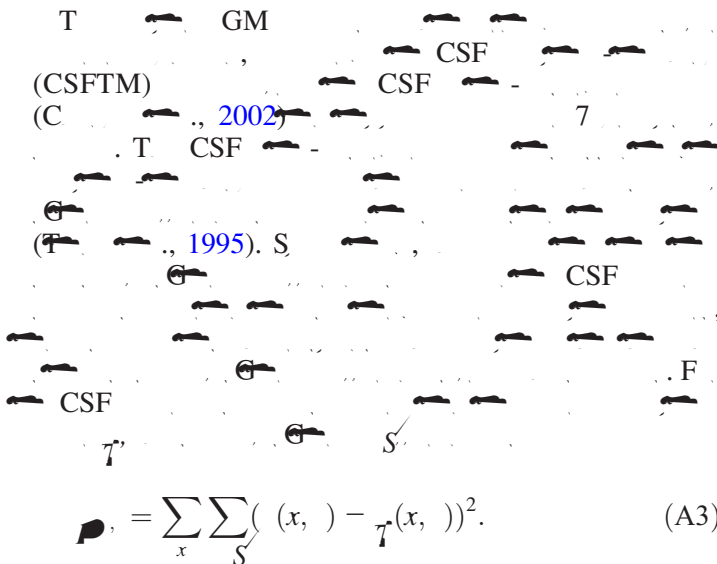


CHOICE Model CMs and R...
Confusion CMs

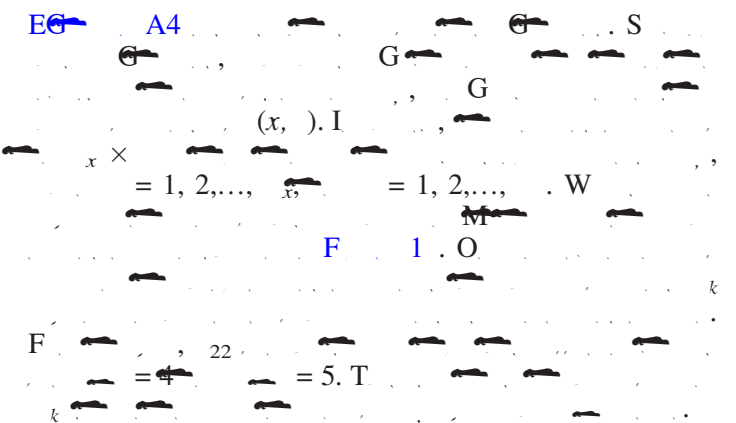
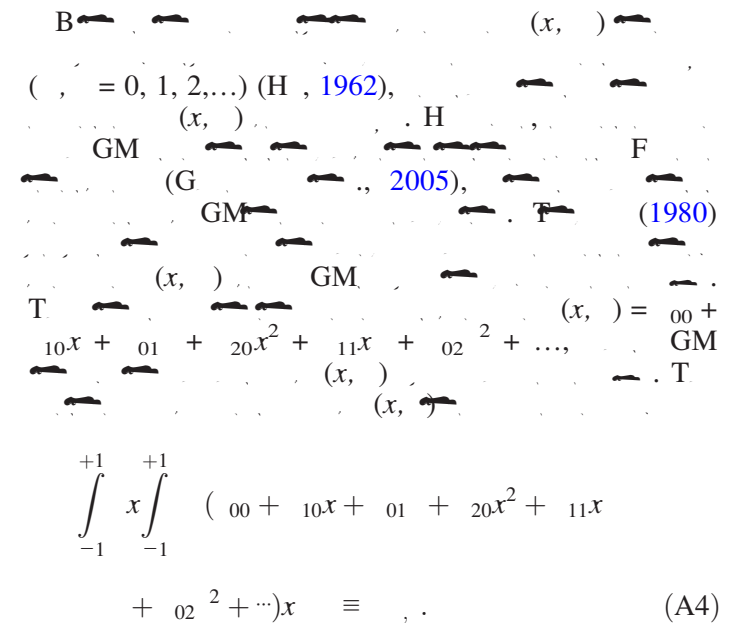




CSF Template-Matching Model (CSFTM)



Reconstruction of a 2-D image with geometric moments



Acknowledgments

T, F, C, NSFC-30725018 (CY), S, G, J, S, B, N, U, P, 111 (L, CY).

C
 C : L L ; C Y .
 E : 7788@ ; @
 A : S O , U A
 B , B , AL 35294, USA; I
 C N E , B N
 U , B 100875, C

G , F., D , S., D , S., & M , R.
 (2005).
 P I C
 M I (ACIDCA-ICMI'05), T
 T .
 G , E. J. (1969).
 N Y : A -C -C .
 G , A. P. (1977).

References

A , H. (1974). A
 , 19, 716 723. T A
 A , F. L. (1962). D
 A , 9,
 240 258.
 B , F. J. (1988). E
 , 3, 199 224. [P M]
 B , V. M., & D , M. V. (1997). W
 G
 C?
 , 37, 2153 2156. [P M]
 B , H. (1971). V
 , 11, 459 474. [P M]
 , F. W., & G , R. W. (1966). O
 , 186, 558 578. [P M] [A]
 C , S. T., L , G. E., & F , B. S. (2002). S
 G
 , 42,
 2137 2152. [P M]
 E , C. W., & S , D. W. (1978). T
 I J R G
 (E .), A
 Y : A P
 (. VII). N
 F , F. L., 3 , K , A., B , G. H., &
 D , I. (1982). N
 A
 , 94,
 91 96. [P M]
 G , W. (1984). P
 A A,
 , 1, 775 782. [P M]
 G , M. J., H , S., L. O., J., & R , J. O. (1984).
 I
 x
 , 10, 655 666. [P M]
 G , D. J., S , J. A., S , J. B., & G , D. M.
 (1979). O
 &
 , 26, 1 19.
 G , L. H., & D W , C. G. (1973). F
 &
 , 14,
 471 482.

b b
 . U . P. D., U .
 , E .
 G , J., B , P. J., & S , A. B. (1999).
 I
 , 39,
 3537 3560. [P M]
 H , M. K. (1962). V
 , 8, 179 187. T
 I T O S (ISO)
 (1986). V : S
 (N ISO 8596). I O
 S
 K , G., & D , S. (1981). R
 &
 , 29, 234 246. [P M]
 , K. R. (1969). C
 : A
 B & J. T. S (E .), T
 : A
 (. VI). N Y : A P
 L B , R. S., & M , J. G. (1985). A
 : A
 &
 , 37, 588 591. [P M]
 L , G. E., H , T. A., K , T. S., S
 M , J. S., & F , B. S. (2002). M . C
 2002: N
 , 42, 2219 2234. [P M]
 L , G. E., P , D. G., R , G. S., & S
 M. M. (1985). P
 —I. N
 , 25, 239 252. [P M]
 L , J. M. (1990). A
 x
 , 16, 106 120.
 [P M]
 L , D. R. (1965). D
 L , R. R. B , & E . (E .), b k
 (. I, . . 103 188). N
 Y : J W S
 L , D. R. (1963). P
 L , R. R. B , & E . (E .), b k
 (. I, . . 245 307). N
 Y : J W S

L., S. J. (1979). O. & , 25, 303-312. [P M]

M., N. J., P., D. G., K., P., & M. (2002). T. G. , 42, 1165-1184. [P M]

M., J. L., & S., D. J. (1974). T. , 20, 525-535. T

M., R., & K., K. R. (1998). S : W S T

N. A. S. N. R. C. (NAS-NRC) (1980). R. , 39. C. , 41, 103-148. [P M]

N., U. (1967). N. Y. : M.

P., D. H., & S., G. (1991). O. G. , 31, 1399-1415. [P M]

P., D. G., B., C. W., B., & M., D. C. (2006). , 46, 4646-4674. [P M]

P., E. C. (1962). P. B. , 53, 409-419. [P M]

R., K., & M. C., G. W. (1976). W. , 16, 829-837. [P M]

S., T. (1991). E. & , 50, 490-497. [P M]

S., G. (1978). E. A. , 6, 461-464.

S., R. S. N. (1987). T. , 237, 1317-1323. [P M]

S., J. A., & P., D. G. (1994). T. , 369, 395-397. [P M]

T., M. (1980). I. A. A., , 70, 920-930. S

T., B. S., B., W. L., L., G. E., & K., D. (1995). H. 3-D , 35, 3053-3069. [P M]

T., B. S., & L., G. E. (1998). T. , 38, 2335-2350. [P M]

T., J. T. (1971). T. & , 9, 40-50.

T., J. T., H., G. G., & H. (1988). F. & , 43, 575-591. [P M]

W., A. B., & A., A. J., J. (2008). P. , 8(4):17, 1-19. :// /8/4/17/, :10.1167/8.4.17. [P M] [A]

Z., J. Y., Z., T., X., F., L., L., & Y., C. (2007). L. C. & , 48, 2383-2390. [P M] [A]