CHAPTER XII

COMPLEMENTARITY PROBLEMS AND THEIR SOLUTIONS Via FIXED POINTS

12.1. The study of complementarity problems came into existence in the early sixties. Since then a variety of research papers appeared in this field. Particularly the explicit complementarity problems and implicit complementarity problems were discussed and studied by many authors. For details we refer to [2], [8], [6], [18], [59], [60], [74]-[81], [95], [96], [112], [121], [130].

In this chapter we consider a more general class of complementarity problem called simultaneous complementarity problem and study the existence and uniqueness of its solution via fixed point. We note that our result includes many known results as special cases.

12.2 Let \( <E, E^*> \) be a dual system of locally convex spaces and let \( K \subset E \) be a closed convex cone. Let \( K^* \) be the dual of \( K \).

i.e. \( K^* = \{ u \in E^* : \langle x, u \rangle > 0 \, \forall \, x \in K \} \). Let \( f : K \rightarrow E^* \) and \( g : K \rightarrow E \). The explicit complementarity problem and the implicit complementarity problem are as follows:

(E.C.P) Find \( x_0 \) in \( K \) such that \( f(x_0) \in K^* \) and \( \langle x_0, f(x_0) \rangle = 0 \).

(I.C.P) Find \( x_0 \) in \( K \) such that \( f(x_0) \in K^* \), \( g(x_0) \in K \) and \( \langle g(x_0), f(x_0) \rangle = 0 \).

For mappings \( f, f_2 : K \rightarrow E^* \) and \( g : K \rightarrow E \), we consider the following simultaneous explicit complementarity problem and implicit complementarity problem.

S.E.C.P\((f, f_2, K)\) : Find \( x_0 \) in \( K \) such that \( f_1(x_0) \in K^* \), \( f_2(x_0) \in K^* \) and

\[
\langle x_0, f_1(x_0) \rangle = 0 \quad \text{and} \quad \langle x_0, f_2(x_0) \rangle = 0.
\]

S.I.C.P\((f, f_2, g)\) : Find \( x_0 \) in \( K \) such that \( f_1(x_0) \in K^* \), \( f_2(x_0) \in K^* \), \( g(x_0) \in K \) and

\[
\langle g(x_0), f_1(x_0) \rangle = 0 \quad \text{and} \quad \langle g(x_0), f_2(x_0) \rangle = 0.
\]

Remark 1 : For \( f_1 = f_2 \) and \( n = 1 \), the problem S.E.C.P\((f, f_2, K)\) contains E.C.P as a particular case.

Remark 2 : For \( f_1 = f_2 \) and \( n = 1 \), the problem S.I.C.P\((f, f_2, K)\) contains I.C.P as a particular case.
Remark 3: If we take \( n = 1 \) and \( g(x_0) = x_0 \cdot m(x_0) \) where \( m \) is a point to point mapping from \( X \) to itself then the problem \( S.I.C.P(f_1, f_2, g, K) \) reduces to the problem of finding \( x_0 \) in \( K \) such that \( f_1(x_0) \in K^* \), \( f_2(x_0) \in K^* \) and \( <x_0, f_1(x_0)> = 0 \) and \( <x_0, m(x_0) f_1(x_0)> = 0 \).

We note that the strongly nonlinear quasicomplementarity problem discussed in [179] is a particular case of the above problem.

Remark 4: If we take \( n = 1 \) and \( g \) to be the identity mapping then the problem \( S.I.C.P(f_1, f_2, g, K) \) reduces to the problem of finding \( x_0 \) in \( K \) such that \( f_1(x_0) \in K^* \), \( f_2(x_0) \in K^* \) and \( <x_0, f_1(x_0)> = 0 \) and \( <x_0, f_2(x_0)> = 0 \).

We note that a particular case of the above problem have been discussed and studied by Noor [131]-[132].

Let \((H, \langle \cdot, \cdot \rangle)\) be a Hilbert space and \( K \subseteq H \) be a closed convex cone. If \( D \subseteq H \) is a subset of \( H \) and \( f_1, f_2, g : D \rightarrow H \) are two mappings, we consider the following simultaneous implicit complimentarily problem:

\[(S.\text{I.C.P.}) \text{ : find } x_0 \text{ in } D \text{ such that } g(x_0) \in K, \ f_1(x_0) \in K^*, \ f_2(x_0) \in K^*, \ \langle g(x_0), f_1(x_0) \rangle = 0 \text{ and } \langle g(x_0), f_2(x_0) \rangle = 0.\]

If \( P_k \) denotes the projection onto \( K \), then we have the following

**Proposition 12.1** [39]: For every element \( x \) in \( H \), \( P_k(x) \) is characterised by the following properties

1) \( \langle P_k(x) - x, y \rangle > 0 \) for all \( y \) in \( K \)

2) \( \langle P_k(x) - x, P_k(x) \rangle = 0. \)

Our main result is based on the following fixed point theorem, [157]

**Theorem 12.1.** Let \( P \) and \( Q \) be mappings on a complete metric space. If there exists a positive integer \( m \) and a positive number \( h < 1 \) such that \( d(P^n(x), Q^n(x)) < h \cdot d(x, y) \) for all \( x \) and \( y \) in \( X \), then \( P \) and \( Q \) have a unique common fixed point.

**Definition 12.1:** Let \( D \subseteq H \) and consider the mappings \( f_1, f_2, g : D \rightarrow H \). We say that \( f_1 \) and \( f_2 \) are pairwise \( n \)-Lipschitz mapping with respect to \( g \) if there exists some
\( \beta > 0 \) such that \( \|f_1^*(x) - f_2^*(y)\| = \beta \|g(x) - g(y)\| \\

**Definition 12.2**: Let \( D \subseteq H \) and consider the mappings \( f_1, f_2, g : D \rightarrow H \). We say that \( f_1 \) and \( f_2 \) are pairwise n-Strongly monotone mapping with respect to \( g \) if there exists some \( \alpha > 0 \) such that \( \langle f_1^*(x) - f_2^*(y), g(x) - g(y) \rangle > \alpha \|g(x) - g(y)\|^2 \) for all \( x, y \) in \( D \).

**Theorem 12.2**: Let \( H \) be a Hilbert space and \( K \subseteq H \) be a closed convex cone. If, for a subset \( D \subseteq H \), the mappings \( f_1, f_2, g : D \rightarrow H \) satisfy the following

(12.2.1) \( f_1 \) and \( f_2 \) are pairwise n-strongly monotone with respect to \( g \)

(12.2.2) \( f_1 \) and \( f_2 \) are pairwise n-Lipschitz with respect to \( g \)

(12.2.3) there exists a real number \( \sigma > 0 \) such that \( \sigma \beta^3 < 2 \alpha < 1/\sigma + \sigma \beta^3 \)

where \( \alpha \) and \( \beta \) are as in definitions 12.1 and 12.2 respectively

(12.2.4) \( K \subseteq g(D) \)

Then the problem (S.I.C.P) is solvable. Moreover if \( g \) is one-one then problem (S.I.C.P) has a unique solution.

**Proof**: Using (12.2.4) we consider the mappings \( h_1, h_2 : K \rightarrow H \) defined by \( h_1(u) = f_1^*(x) \) and \( h_2(u) = f_2^*(x) \), where \( x \) is an arbitrary element of \( g^*(u) \) and \( u \in K \). Since \( f_1 \) and \( f_2 \) are pairwise n- strongly monotone and n- Lipschitz with respect to \( g \), \( h_1 \) and \( h_2 \) will have the following properties:

(12.2.5) \( \langle h_1^*(u) - h_2^*(v), u - v \rangle > \alpha \|u - v\|^2 \)

(12.2.6) \( \|h_1^*(u) - h_2^*(v)\| \leq \beta \|u - v\| \)

We now see that (S.I.C.P) is equivalent to the following complimentarity problem.

Find \( u \) in \( K \) such that \( h_1(u) \in K^* \). \( h_1(u) \in K^* \), \( \langle u, h_1^*(u) \rangle > 0 \) and \( \langle u, h_2^*(u) \rangle = 0 \). From proposition 12.1 we see that the above problem has a solution iff, the mappings \( T_1, T_2 : K \rightarrow H \) defined by \( T_1^*(u) = P_k(u - \sigma h_1^*(u)) \) and \( T_2^*(u) = P_k(u - \sigma h_2^*(u)) \) (where \( \sigma \) is the real number defined in (12.2.3) has a common fixed point

\[
\|T_1^*(u) - T_2^*(v)\|^2 = \|P_k(u - \sigma h_1^*(u)) - P_k(v - \sigma h_2^*(v))\|^2 \\
\leq \|u - \sigma h_1^*(u)) - (v - \sigma h_2^*(v))\|^2
\]

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Using assumption (12.2.3) and the facts that every Hilbert space is a complete metrically convex metric space and every metrically convex space is locally convex, we see that \( T_1 \) and \( T_2 \) satisfy all assumptions of theorem 12.1. Hence \( T_1 \) and \( T_2 \) has a unique common fixed point.
A. Aleksiewicz

1. The two norm spaces,

G. Allen

2. Variational inequalities, complementarity problems and duality theorems,

R. Badard

3. Fixed point theorems for Fuzzy metric spaces,

S. Banach

4. Théorie les operations Linéaires,
   Monogranie Mathematyczne, Warsaw, 1932.

A.T. Barucha-Reid

5. Fixed point theorems in probabilistic analysis,

J.M. Barwein

6. Generalised linear complementarity problems treated without fixed point theory,

R. Baskaran and W.A. Kirk

7. Fixed point theorems for set valued mappings of contractive type,

M.S. Bazara, J.J. Gode and M.Z. Nashed

8. A nonlinear complementarity problem in mathematical programming in Banach
spaces,

S.A. BELBAS and I.D. MAYERGOYD

9. Applications of fixed point methods,

R. Bellman and E. S. Lee

10. Functional equations arising in dynamic programming,

A. Bensoussan


A. Bensoussan, M. Goursat and J. L. Lions

12. Contrôle impulsionelle et inéquations quasi-variationelles stationnaires,

A. Bensoussan and J. L. Lions

13. Applications des inéquations variationnelles en contrôle stochastique,
Paris, Dunod 1978

14. Nouvelle formulation de problèmes de contrôle impulsionnel et applications,

15. Nouvelles méthodes en contrôle impulsionnel,

16. Problèmes de temps d'arrêt optimal et inéquations variationnelles paraboliques,

A. BERMAN and R. J. PLEMMONS

17. Non negative matrices in mathematical sciences,
New York, Academic Press 1979

134
18. The complementarity problems: theory and complementarity problem in mathematical programming in Hilbert space.


P.C. Bhakta and Sumitra Mitra


G. Bocsan

20. On some fixed point theorems in probabilistic metric spaces.

D. Butnariu

Fuzzy sets and systems, 7(1982), 191-207.

G.L. Cain and R.H. Kasriel

22. Fixed and periodic points of local contraction mappings on probabilistic metric spaces.

J.L.C. Camargo

23. A common fixed point theorem for two operators in locally convex spaces.

K.P. Chamola

24. Fixed points of mappings satisfying a new contraction condition in Randor normed spaces.
C.C. Chang

25. On a fixed point theorem of contractive type mappings,

S.S. Chang

26. A common fixed point for commuting mappings,

27. On common fixed points for a family of \$\phi\$-contraction mappings

28. On some fixed point theorems in PM - spaces and its applications,


29. Common fixed point for four maps on a metric space,

Y.J. Cho, M S. Khan and S L. Singh

30. Common fixed points of weakly commuting mappings,

Y.J. Cho, P P. Murthy and M Stojakovic

31. Compatible mappings of type(A) and common fixed points in Menger spaces,

Y.J. Cho and S L. Singh

32. A coincidence theorem and fixed point theorems in saks spaces,
Kobe J. Math. 3 (1986), 1-6

33. An approach to fixed points in saks space,
Annals de la Soc. Sci. de Bruxelles, t. 98 II-III (1984), 80-84

I. Ilić Ciric

34. On fixed points of generalised contractions on probabilistic metric spaces,

V. Conserva

35. Common fixed point theorems for commuting maps on a metric space,

R. S. Cottle

36. Numerical methods for complementarity problems in engineering and applied sciences,

R. W. Cottle and J. S. Pang

37. A least element theory of solving linear complementarity problems as linear programs,

C. W. Cryer and M. A. H. Dempster

38. Equivalence of linear complementarity problems and linear programs in vector lattice Hilbert spaces,

S. Czerwik

39. Generalization of Edelstein’s fixed point theorem,

40. A fixed point theorem for a system of multivalue transformations,

137
K. M. Das and K. V. Nair

41. Common fixed point theorems for commuting maps on a metric space,

R. Dedeic and N. Sarappa

42. A common fixed point theorem for three mappings on Menger spaces,

D. Delbesco, O. Ferrero and F. Rossati

43. Teoremi di punto fisso per applicazioni negli spazi di Banach,

X.P. Ding

44. Some common fixed point theorems of commuting mappings II,

M.L. DiVicarro, B. Fisher and S. Sessa

45. A common fixed point theorem of Gregus type,

I.C. Dolcetta, M. Lorenzani and F. Spizzichino

46. A degenerate complementarity system and application to the optimal stopping
    of the Markov chains,

I.C. Dolcetta and V. Mosco

47. Implicit complementarity problems and quasi-variational in equalities,
    in R.W. Cottle, F. Gianessi and J.L. Lions eds: Variational
    inequalities and complementarity problems, Theory and Appl.
    (John Willey and Sons 1980), 75-87.

G. Duvaut and J.L. Lions

48. Inequalities in mechanics and physics,

M. Edelstein

49. On fixed and periodic points under contraction mappings,

R. J. Egbert

50. Products and quotients of probabilistic metric spaces,

J. X. Fang

51. On fixed point theorems in fuzzy metric spaces,
    Fuzzy sets and systems, 46 (1992), 107-113.

B. Fisher

52. Common fixed point and constant mapping on metric space,

53. Common fixed points of commuting mappings,

54. Common fixed points of four mappings,

55. Common fixed points on a Banach space,
    Chung Yuan J. 11 (1982), 12-15

56. Mappings with common fixed point,
    Math. Sem. Notes Kobe Univ. 7 (1979), 81-84; addendum 8 (1980).

57. Three mappings with a common fixed point,

B. FISHER and S. SESSA

58. On a fixed point theorem of Gregus,

T. Fujimoto

59. An extension of Tarski's fixed point theorem and its application to isotone
    complementarity problems,

60. Nonlinear complementarity problems in a function space,

S. Gähler


K. Goebel


M. Grabiec


M. Gregus Jr


O. Hadzic


69. Common fixed point theorems for a family of mappings in complete metric spaces, Math. Japon. 29(1984), 127-134.
On the $(\epsilon, \delta)$- topology of $LP^\infty$-spaces,
Glasnik Mat. 13(33) (1978), 293 - 297

Some theorems on fixed points in probabilistic metric and random normed
spaces,

T.L. Hicks

72. Fixed point theory in probabilistic metric spaces,
63-72.

M. Imdad, M.S. Khan and M. D. Khan

73. A common fixed point theorem in 2-metric spaces,

G. Isac

74. Complimentarity problem and coincidence equations on convex cones,

75. Nonlinear complimentarity problem and galerkin method,

76. On the implicit complimentarity problem in Hilbert spaces,

77. Problems de complimentarite (En dimension infinie),

78. Sur l'existence par comparison des valeurs propres positives pur
des operateurs non-linearies,

79. Un Theorem de point fixe, Application au probleme d'optimisation d'ersov
Seminari dell, instituto di mat. applicata, Universita de Firenze.
Complimentarity problems and post critical equilibrium state of thin elastic plates,

A variational principle, Application to the nonlinear complimentarity problem

K. Iseki

Some applications of Banach type contraction principles,

A property of orbitally continuous mappings on 2- metric spaces,
Math. Seminar notes, Kobe Univ. 3(1975), 131-132.

Fixed point theorems in 2-metric spaces,
Math. Seminar notes, Kobe Univ. 3(1975), 133-136.

K. Iseki, P.L. Sharma and B.K. Sharma

Contraction type mappings on 2-metric spaces,

I. Istratescu

A fixed point theorem for mappings with a probabilistic contractive iterate,

G. Jungck

Common fixed points for commuting and compatible maps on compacta,

Commuting mappings and fixed points,

Compatible mappings and common fixed points,
90. Compatible mappings and common fixed points (2),

91. Periodic and fixed points of commuting maps,

G. Jungck, P.P.Murthy and Y.J Cho

92. Compatible mappings of type (A) and common fixed points,

S.M. Kang, Y.J.Cho and G.Jungck

93. Common fixed point of compatible mappings,

S.M. Kang and Y.P.Kim

94. Common fixed point theorems,
Math. Japonica, 6(37), 2-10.

S. Karamardian

95. Generalised complimentarity problem,

96. The nonlinear complimentarity problem with application,

S. Kasahara

97. On some recent results on fixed points (ii),

M.D. Khan

98. A study of fixed point theorems,

M.S. Khan

99. Common fixed point theorems for a family of mappings,

100. Convergence of sequences of fixed points in 2- metric spaces
Indian J Pure Appl Math 10(1979), 1062-1067.

101. Remarks on some fixed point theorems ,
ibid, 18(1982), 375-379

102. On fixed point theorems in 2-metric spaces ,
Publ Inst Math (Beogr) (N.S), 41(1980), 107 - 112.

M.S. Khan and B Fisher

103. Some fixed point theorems for commuting mappings ,

M.S. Khan and M. Imdad

104. Some common fixed point theorems ,
Glasnik Mat. 18(38)(1983), 321-326.

M.S. Khan, M. Imdad and M. Swaleh

105. Assymptotically regular maps and sequences in 2-metric spaces ,

M.S. Khan and M. Swaleh

106. Results concerning fixed points in 2-metric spaces ,

I. Kramosil and J. Michalek

107. Fuzzy metric and statistical metric spaces ,
Kybernetika, 11 (1975), 336-344.

T. Kubaiik

108. Common fixed points of pair wise commuting mappings ,

C. Kulshreshta

109. Single valued mappings, multivalued mappings and fixed point theorems in metric spaces ,
Doctoral Thesis , Garhwal Univ. (Srinagar)1983 

144
S. N. Lal and A. K. Singh

110. An analogue of Banach's contraction principle for 2-metric spaces,  

111. Invariant points of generalised nonexpansive mappings in 2-metric spaces,  

G. Lami

112. A remark on the complimentarity problem,  

O. L. Mangasarian

113. Equivalence of complimentarity problems to a system of non linear equations  

114. Iterative solution of linear programs,  

J. Matkowski

115. Integrable solutions of functional equations,  

116. Some inequalities and a generalization of Banach's Principle,  

B. A. Meade and S. P. Singh

117. On common fixed point theorems,  

K. Menger

118. Statistical metrics,  

S. N. Mishra

119. Common fixed points of compatible mappings in PM-spaces,  
S.N. Mishra, N. Sharma and S.L. Singh

120. Common fixed points of maps on fuzzy metric spaces,

G. Mitra

121. An exposition of the (linear) complimentarity problems,

V. Mosco

122. On some non linear quasi variational inequalities and implicit
complementarity problems in stochastic control theory,
(John Willey and Sons 1980) 271 - 283.

R.N. Mukherjee and V. Verma

123. A note on a fixed point theorem of Gregus,


124. Compatible mappings of type (A) and common fixed point theorems,

P.P. Murthy, Y.J. Cho and M. Stojakovik

125. Compatible mappings of type (A) and common fixed point theorems in Menger
spaces,

P.P. Murthy and B.K. Sharma

126. Some fixed point theorems on saks space,

S.V.R. Naidu and J.R. Prasad

127. Fixed point theorems in 2-metric spaces,

S.A. Naimpally and K.L. Singh

S.A. Naimpally, S.L. Singh and J.H. M. Whitfield

129. Coincidence theorems.

S. Nanda and S. Nanda

130. A nonlinear complementarity problem in mathematical programming in Hilbert spaces,

M.A. Noor


132. On the nonlinear complementarity problem,

T. Okada

133. Coincidence theorems on L-spaces,

W. Orlicz

134. Linear operations in Saks spaces (I),

135. Operations in Saks spaces (II),

W. Orlicz and V. Ptak

136. Some results on Saks spaces,
Stud. Math. 16(1957), 56-68.

J.S. Pang

137. On the convergence of a basic iterative method for the implicit complementarity problem,

R.P. Pant

139. Common fixed points of two pairs of commuting mappings,

S. Park

140. Fixed points of $I$-contractive type maps,

141. A generalisation of a theorem of Janos and Edelstein,

S. Park and B.E. Rhoades

142. Meer-Keeler type contractive conditions,

H.K. Pathak

143. A Meer-Keeler type fixed point theorem for weakly uniformly
 contraction maps,

H.K. Pathak and R.P. Dubey

144. Extensions of a fixed point theorem of Naimpally and Singh,

H.K. Pathak and Reny George

145. A common fixed point theorem of Gregus type for compatible mappings
 and its application,

H.K. Pathak, Reny George and Rekha Sharma

146. Extensions of some fixed point theorems of Naimpally and Singh,

H.K. Pathak, Reny George and D.N. Yadav

147. Common fixed point for five maps,
Poincaré

148. Analysis situs,
J. del Ecole Polytech 2(1)(1895), 1-123

V. Radu

149. On some contraction principles in Menger spaces,

150. On some contraction type mappings in Menger spaces,

151. On t-norm of the Hadzic type and fixed points in the probabilistic metric spaces

B. Ram

152. Existence of fixed points in 2-metric spaces,

I.M.N. Rao, and K.P.R. Rao

153. Common fixed point for the maps on a metric space,

B.K. Ray

154. Remarks on a fixed point theorem of Gerald Jungck,

K.B. Reddy and P.V. Subrahmanyam

155. Altman's contractors and Matkowski's fixed point theorem,

K.B. Reddy and P.V. Subrahmanyam

156. Extensions of Krasnoselskii's and Matkowski's fixed point theorems,

B.E. Rhoades

157. A comparison of various definitions of contractive mappings,
158. **Contactive definitions revisited**,  
Topological methods in non linear functional analysis,  

159. **Contraction type mappings on a 2-metric spaces**,  

**B.E. Rhoades and S. Sessa**

160. **Common fixed point theorems for three maps under a weak commutativity condition**,  

**B.E. Rhoades, S. Sessa, M.S Khan and M.D Khan**

161. **Some fixed point theorems for Hardy-Rogers type mappings**,  

**B.E. Rhoades, S. Sessa, M.S Khan and M Swaleh**

162. **On fixed points of asymptotically regular mappings**,  

**B. Schweizer and A. Sklar**

163. **Probabilistic metric spaces, vol. 5**,  

164. **Statistical metric spaces**,  

**V.M. Sehgal and A T.Barucha - Reid**

165. **Fixed points of contraction mappings on probabilistic metric spaces**,  
Math. Systems Theory, 6 (1972), 97 - 102

**N. Serstnev**

166. **The notion of random normed spaces**,  

**S. Sessa**

167. **On a weak commutativity condition of mappings in fixed point considerations**,  
S. Sessa and B. Fisher

168. Common fixed points of weakly commuting mappings, 

S. Sessa, R. N. Mukherjee and T. Som

169. A common fixed point theorem for weakly commuting mappings, 
Math. Japon. 31 (1986), 235-245

S. Sessa, B. E. Rhoades and M. S. Khan

170. On common fixed points of compatible mappings in metric and Banach spaces 

A. K. Sharma

171. A generalisation of Banach contraction principle in 2-metric spaces, 
Math. Seminar notes, Kobe Univ. 7(1979), 291-292.

172. A note on fixed points in 2-metric space, 

173. A study of fixed points in metric and 2-metric spaces, 

174. On Fixed points in 2-metric spaces, 
Math. Seminar notes, Kobe Univ. 6(1978) 467-473.

H. Sherwood

175. Complete probabilistic metric spaces, 

176. On E-spaces and their relations to other classes of probabilistic metric spaces 

177. On the completion of probabilistic metric spaces, 

A.P. Shostak

178. Two decades of fuzzy topology, basic ideas notions and results, 
Russian Math. Surveys, 44.6(1989), 123-186
A.H. Siddiqi and Q.H. Ansari

179. Strongly non linear quasi variational inequality.

S.L. Singh

180. Some common fixed point theorems in L Spaces,

181. A fixed point theorem in 2-metric spaces,

182. Some contraction type principles on 2-metric spaces and applications,
Math. Seminar Notes, Kobe Univ., 7 (1979), 1-11.

183. On common fixed points of commuting mappings,
Math. Seminar Notes, 5 (1977), 131-134.

S.L. Singh and U.C. Gairola

184. A coincidence theorem for three systems of transformations,

185. A general coincidence theorem,

186. A general fixed point theorem,

S.L. Singh, U.C. Gairola and R. Mehandiratta

187. A coincidence theorem for three systems of transformations,

S.L. Singh and S. Kasahara

188. On some recent results on common fixed points,

S.L. Singh and C. Kulshreshta

189. A common fixed point theorem for two systems of transformations,
S. L. Singh and B. R. Pant

190. Coincidence and fixed point theorem for a family of mappings in menger spaces and extension to uniform spaces,

191. Fixed point theorems for commuting mappings in probabilistic metric spaces

192. Common fixed point theorem in probabilistic spaces and extension to uniform spaces,

S. L. Singh and J. Ram

193. Common fixed points of commuting mappings in 2-metric spaces

194. Note on the convergence of sequence of mappings and their common fixed points in a 2-metric space,

S. L. Singh and S. P. Singh

195. A fixed point theorem,

S. L. Singh and B. M. L. Tiwari

196. Common fixed points of mappings in complete metric spaces,

S. L. Singh, B. M. L. Tiwari and V. K. Gupta

197. Common fixed points of commuting mappings in 2-metric spaces and applications,

S. L. Singh and Virendra

198. Coincidence theorems on 2-metric spaces,

A. Spacek

199. Note on K. Mengers probabilistic geometry.

Czechoslovak Math J 6(1956), 72-74

M Stojakovic

201. A common fixed point theorems in probabilistic metric spaces and its applications,
Glasnik Mat. 23(43) (1988), 201-211

201. Common fixed point theorems in complete metric and probabilistic metric spaces,

202. Fixed point theorems in probabilistic metric spaces,

N.X. Tan

203. Generalised probabilistic metric spaces and fixed point theorems,

B.M.L Tivati and S.L.Singh

204. A note on recent generalizations of Jungck contraction principle,
J. UPGC. Acad. Soc 3 (1986), 13-18

R.S. VARGA

205. Matrix iterative analysis,
Englewood Cliff, NJ, Prentice Hall 1962

R. Vasuki

206. A fixed point theorem for a sequence of maps satisfying a new contraction type
condition in Menger spaces,

A. Wald

207. On a statistical generalisation of metric spaces,
Proc. Nat. Acad. Sci., U.S A 29(1943) , 196 - 197

M.D. Weiss

208. Fixed points, separation and induced topologies for fuzzy sets,
C C Yeh

209. On common fixed point theorems of continuous mappings,

L A Zadeh

210. Fuzzy sets,
Inform. Control, 8 (1965), 338-353

E H Zarantonello

211. Projections on convex sets in Hilbert space and spectral theory,