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Oturum Başkanı	Oturum Başkan Yrd.
Prof.Dr. Uğur Yüzgeç	

Sıra	Yazar Bilgisi	Bildiri Bilgileri
15:00	Yüksek Lisans Öğrenci Cihat Doğan - Prof.Dr. Uğur Yüzgeç	Hızlandırılmış Karşıt Öğrenme Tabanlı Tek Aday Optimizasyon Algoritması
15:15	Yüksek Lisans Öğrenci Cihat Doğan - Prof.Dr. Uğur Yüzgeç	Kümeleme Problemleri İçin Karşıt Öğrenme Tabanlı Tek Aday Optimizasyon Algoritması
15:30	Dr. Öğretim Üyesi Yasemin Samav	Sustainability in Polymeric Wastes
15:45	Dr. Öğretim Üyesi Feridun Karakoç - Fatih Enes Alp - Arş.Gör.Dr. Melih Canlıdinç - Arş.Gör. Ahmet Dayanç	Sıvı Yakıtlı Roket Motorlarının Hesaplamalı Analizi: Ch4+o2 ve Flp Yakıt Karışımları Üzerine Bir Çalışma
16:00	Araştırmacı Ali Kocaman	Farklı Zemin Sınıflarında Düşey Elastik Tasarım Spektrumlarının Kirişlere Etkisi ve K.Maraş Deprem ile Karşılaştırılması
16:15	Soru, cevap ve tartışma	

İÇİNDEKİLER

EĞİTİM VE SOSYAL BİLİMLER

MAKALE İSMİ	YAZARLAR	SAYFA NO
MESLEKİ TÜKENMİŞLİK KAVRAMI VE MESLEKİ TÜKENMİŞLİK DÜZEYİNİN DEMOGRAFİK DEĞİŞKENLER AÇISINDAN İNCELENMESİ	OĞUZHAN MEHMET ÇELİK	1
KÜLTÜREL SERMAYE KÜLTÜR ENDÜSTRİSİNE KARŞI: BİR BOURDİEU-FRANKFURT OKULU TARTIŞMASI	ARMAĞAN ÖZTÜRK	12
METAVERSE KAVRAMSALLAŞTIRMASI ÜZERİNE YENİ İLETİŞİM ORTAMLARIMDA KAMUSAL ALAN VE BENLİK SUNUMU	TARKAN ÖZTÜRK, ÜMİT SARI	24
RÜYA KANITI	FATİH ÖZGÖKMAN	35
EVRİM TEORİSİ VE NEDENSELLİK İLKESİ	FATİH ÖZGÖKMAN	40
SAĞLIK ÇALIŞANLARINDA MERHAMET YORGUNLUĞU	FATOŞ MUTLU AĞGÜL, CUMA SUNGUR	44
OKUL ÖNCESİ ÖĞRETMENLERİNİN TOPLUMSAL CİNSİYETE YÖNELİK SINIF İÇİ ALGILARININ İNCELENMESİ	ELİF MANYASLI ZENGİN, ÜMİT DENİZ	51
FEN ÖĞRETİMİNDE OYUNLA ÖĞRETİM YÖNTEMİ İLE İLGİLİ YAPILAN ÇALIŞMALAR ÜZERİNE BİR İNCELEME	SITTIKA BAŞPINAR	64
ORTAK DİKKAT ETKİNLİKLERİNİN ÇOCUKLARIN ORTAK DİKKAT BECERİSİNİN GELİŞİMİ ÜZERİNDEKİ ETKİLERİ	ZEYNEP MERVE UZBAŞ, MELİKE KILIÇ, MUHAMMED ŞÜKRÜ AYDIN	75
SUSTAİNABLE FASHİON: AN OVERVİEW OF TURKİSH BİG MANİFACTURERS AND BOUTİQE BRANDS	BİLGE SENA ÖZ, ZEHRA DOĞAN SÖZÜER	83
SOSYAL KATILIM ÖLÇEĞİ: ÖLÇEK GELİŞTİRME ÇALIŞMASI	BÜŞRA NUR GÜNTEKE, SONER ALADAĞ	94
UNRAVELİNG MEDİA MANİPULATİON: EXPLORİNG RUSSİA'S UTİLİZATİON OF MEDİA AS A STRATEGİC INSTRUMENT İN FOREİGN POLİCY	ATA TAHA KUVELOĞLU	104
DİYALOJİK OKUMANIN İLKOKUL DÖRDÜNCÜ SINIF ÖĞRENCİLERİNİN KONUŞMA BECERİLERİNE ETKİSİ	GÖKÇE GÜCÜM, BERKER BULUT	111
SINIF ÖĞRETMENLERİNİN OYUNLAŞTIRMA YÖNTEMİ HAKKINDAKİ GÖRÜŞLERİNİN ÇEŞİTLİ DEĞİŞKENLER AÇISINDAN İNCELENMESİ	GÖKÇE GÜCÜM, BERKER BULUT	120
İŞLETMELERDE ONLİNE EĞİTİMİN PERSONEL ÜZERİNE ETKİLERİNİN DEĞERLENDİRİLMESİ.	COŞKUN ÖZDOĞAN, ALİ ÖZKURT	128
VİZYONER BELEDİYECİLİK VE İNSAN ODAKLI SÜRDÜRÜLEBİLİR ÇÖZÜMLER	NİHAT KURT	137
TÜRKİYE'YE GÖÇ ETMİŞ OLAN IRAK'LI GÖÇMENLERİN İNANCA YÖNELİK TUTUMLARINDAKİ DEĞİŞMELER: SAMSUN İLİ ÖRNEĞİ	SONGÜL ÇIRNIK, MURAT ŞAHİN	148
TÜRKİYEDE MİLLİYETÇİ PARTİLERİN OY YOĞUNLUĞU VE GEÇİCİ KORUMA STATÜSÜNDEKİ SURİYELİLERİN NÜFUS İÇİNDEKİ YOĞUNLUKLARI ARASINDAKİ İLİŞKİNİN İNCELENMESİ	MAHMUT TURAN EKTİREN	161
HAVACILIK SEKTÖRÜNDE YER HİZMETLERİ ÇALIŞANLARININ İŞE ALIM KRİTERLERİNİN BELİRLENMESİ	NURTEN ŞAHİNKAYA, ÖMER EMRE ARSLAN	172
DİJİTAL DÖNÜŞÜMÜN STRATEJİK YÖNETİM PERSPEKTİFİYLE DEĞERLENDİRİLMESİ	EKREM SÜZEN, MURAT BAŞAL	181
LİSE ÖĞRENCİLERİNE YÖNELİK “İNTERNET ÖZGECİLİĞİ” ÖLÇEĞİ GELİŞTİRME ÇALIŞMASI	SÜMEYYE BİLGİZ AKBAYIR, ADEM PEKER	186
TRAJİK İYİMSERLİK KAVRAMININ İNCELENMESİ	AYŞENUR AYVAZ, HATİCE ŞINGIR	196
ORTAOKUL ÖĞRENCİLERİNİN SOSYAL YAŞAM DENEYİMLERİNİN FARKLILIKLARININ MATEMATİKSEL MODELLEME SÜRECİNE ETKİSİNİN İNCELENMESİ	ORKUN COŞKUNTUNCEL, FATİH KALE, ORHAN YURTALANOĞLU	203
MECELLE’DE İCÂRE AKDİNDE MUHAYYERLİK KONUSUNUN İNCELENMESİ	M. ZÜLFİKAR FIRAT	214
PMC İLE ASKERİ ÖZELLEŞMENİN ULUSAL GÜVENLİK RİSKİ : WAGNER ÖRNEĞİ	GİZEM ŞAHİN, GÖRKEM ARDACAN TAN	233

EKONOMİ TARİHİNDE YENİ YÖNELİMLER: BİR BİBLİOMETRİK ANALİZ	KAZIM BAYCAR, MEHMET TURAN DAL	244
TÜRKİYE CUMHURİYET MERKEZ BANKASININ PARA POLİTİKASI TERCİHLERİ VE PARA POLİTİKASI TERCİHLERİNİN FİNANSAL PİYASALARA ETKİLERİ	SUENNUR GÜRCAN	250
KORONAVİRÜS SÜRECİNDE MEDYA İNFODEMİSİ: TWİTTER ÖRNEĞİ	AYLİN İZMİR, MUHACİR MURAT YEŞİL	258
37. CUMHURİYET HÜKÜMETİNDE MSP'NİN KOALİSYON PROTOKOLÜ ÜZERİNDEN DEĞERLENDİRİLMESİ	MUHAMMED RECEP KILIÇ	270

FEN VE MÜHENDİSLİK BİLİMLERİ

MAKALE İSMİ	YAZARLAR	SAYFA NO
KEMOMETRİ TASARIM YÖNTEMİ KULLANILARAK DESLORATADİN TAYİNİ	NERGİZ KÜÇÜKGACAL, SEYFULLAH KEYF	278
VARYANS ANALİZİ (ANOVA) KULLANILARAK DOYMAMIŞ POLYESTER REÇİNENİN ÖZELLİKLERİNİN İNCELENMESİ	BİRCAN TINMAZ ÖZBEK, SEYFULLAH KEYF	290
OZON GAZININ TEKSTİL SEKTÖRÜNDE UYGULAMALARI	UMUT ÇINAR	300
ALETSEL DÖNEMDEKİ MİDİLLİ DEPREMLERİ VE DEPREM OLUŞ DÜZENİ AÇISINDAN ÖZELLİKLERİ	DOĞAN KALAFAT	311
MİDYE TOPLAMA APARATLARININ GERİLME ANALİZİ	PINAR YILDIRIM, ALMİLA AK	325
YÖNETİCİLER VE LİDERLER İÇİN DİJİTAL VERİMLİLİK	PELİN ALTINIŞIK, ADEM ALTINIŞIK	332
YELKENLİ TEKNELERDE YALPA ÖNLEME İÇİN HAREKETLİ SALMA EKLENTİSİNİN SAYISAL OLARAK İNCELENMESİ	AHMET YURTSEVEN	343
SAMSUN İL MERKEZİ VE ÇEVRESİNDE DEĞİŞİK TRAFİK YOĞUNLUĞUNA SAHİP YOL KENARLARINDA BULUNAN EGZOTİK BİTKİLERDE AĞIR METAL BİRİKİMİ	MERVE ERDOĞAN	351
MEDİKAL BİLGİSAYARLI TOMOGRAFİ GÖRÜNTÜLERİNDEN GAUSS GÜRÜLTÜSÜNÜ FİLTRELEMEK İÇİN OPTİMUM BİR ORTALAMA FİLTRE TASARIMI	VOLKAN GÖREKE	357
COMPARİSON OF DENOİSİNG FİLTERS FOR BRAİN MAGNETİC RESONANCE IMAGES	ÖZLEM ALTIOK, MURAT ALPARSLAN GÜNGÖR	363
HARRAN OVASI YÜZEY ALTI DRENAJ SİSTEMİNİN BAZI PERFORMANS GÖSTERGELERİ	BARIŞ BAHÇECİ	371
MAKİNE ÖĞRENİMİ VE DERİN ÖĞRENME ALGORİTMALARINI KULLANAN ÇEŞİTLİ SALDIRI TESPİT TEKNİKLERİ ÜZERİNE KARŞILAŞTIRMALI BİR ÇALIŞMA	ABDULLAH ASIM YILMAZ, BURAK BAĞDAT	386
DETERMİNİSTİK VE RASTGELE ŞİFRELİ ANAHTAR KELİME ARAMA ŞEMALARI ARASINDA BİR KARŞILAŞTIRMA	ÖZGÜR ÖKSÜZ	396
DENİZYOLU VE DEMİRYOLU TAKİP VE KORUMA SİSTEMLERİ	OĞUZ ÖZTÜRK, EDA TURAN, ZÜBEYDE ÖZTÜRK	405
DEMİR VE DENİZ İPEKYOLU VE BİLGİ SİSTEMLERİ	OĞUZ ÖZTÜRK, EDA TURAN, ZÜBEYDE ÖZTÜRK	415
İKİNCİ DERECEDEN RİCCATİ DİFERANSİYEL DENKLEMLERİ BELL MATRİS SIRALAMA YÖNTEMİ	GÖKÇE YILDIZ NOHUTCU, KÜBRA ERDEM BİÇER	426
DOĞAL VE SENTETİK NÜVELİ KOMPOZİT SANDVİÇ YAPILARIN KARŞILAŞTIRILMASI	ALİ UMMAN YAVUZ, ÇAĞATAY YILMAZ	436
DUFFİNG DİFERANSİYEL DENKLEMLERİN YAKLAŞIK ÇÖZÜMLERİ İÇİN BOOLE POLİNOMLARINA DAYALI BİR SAYISAL YÖNTEM	HALE GÜL DAĞ, KÜBRA ERDEM BİÇER	447
GÜNEŞ ENERJİSİYLE ÇALIŞAN ELEKTRİKLİ ARAÇ ŞARJ İSTASYONLARININ PİK TALEP DÖNEMLERİ VE YENİLENEBİLİR ENERJİ POTANSİYELİ DİKKATE ALINARAK FİZİBİLİTE ANALİZİ	MUSA TERKEŞ, ALPASLAN DEMİRCİ	461
TLPBX3 (X=I, BR, CL, F) PEROVSKİTE MALZEMESİNİN ELEKTRONİK VE YAPISAL ÖZELLİKLERİNİN INCELENMESİ	VEYSEL ÇELİK	472
APPLİCATİON OF A PET, ALUMİNUM, LD/PP COMPOSİTE AND ITS EFFECT TO HEAT AND SOUND INSULATİON ON HEADLİNER	BURAK BARIŞKAN, BAHADIR CETİŞLİ, CAN BİLİR, NACİ UYSAL, EŞREF EGEMEN YILDIRIM, MELİKE TÜRKYILMAZ, GÖKHAN ÖZBEK, HÜSEYİN HEKİMOĞLU	480

FARKLI ZEMİN SINIFLARINDA DÜŞEY ELASTİK TASARIM SPEKTRUMLARININ KİRİŞLERE ETKİSİ VE K.MARAŞ DEPREM İLE KARŞILAŞTIRILMASI	ALİ KOCAMAN	491
HIZLANDIRILMIŞ KARŞIT ÖĞRENME TABANLI TEK ADAY OPTİMİZASYON ALGORİTMASI	CİHAT DOĞAN, UĞUR YÜZGEÇ	506
KÜMELEME PROBLEMLERİ İÇİN KARŞIT ÖĞRENME TABANLI TEK ADAY OPTİMİZASYON ALGORİTMASI	CİHAT DOĞAN, UĞUR YÜZGEÇ	515
SÜRDÜRÜLEBİLİRLİĞİN OTOMOTİV SEKTÖRÜNDEKİ TARİHÇESİ VE GELECEK EĞİLİMLERİ	GÖKHAN AKÇAY	523
ÖN TAMPON IZGARA TASARIMINI ETKİLEYEN FAKTÖRLER	MERVE BOLADINLI ASA, UMUT AKGÜN	531
AISI 2344 VE AISI 2738 ÇELİKLERİNİN TİALN KAPLI KARBÜR TAKIMLAR KULLANILARAK YAPILAN FREZELEME SONRASI SERTLİK VE YÜZEY PÜRÜZLÜLÜKLERİNİN KARŞILAŞTIRILMASI	ENES FARUK KALAYLIOĞLU, MEHMET İPEKOĞLU, AHMET UĞUR BATUK	539
YÜZ GÖRÜNTÜLERİNDE DERİN EVRİŞİMLİ AĞ KULLANAN SÜPER ÇÖZÜNÜRLÜK MODELİ	EMRE ALTINKAYA, BURHAN BARAKLI	554
BAGAJ KAPAĞININ YAPISAL PERFORMANSLARINI DOĞRULAMAK İÇİN KULLANILAN TESTLER	ANIL CAN DÖNMEZ	565
PLASTIK PORTBAGAJ BARI GELİŞTİRME VE YAPISAL DOĞRULAMALARI	ATANUR ACAR, ŞERİF TUTAR, ÖZGE MÜGE KANGAL, TAMER AYDINER, ONUR GÜDEK	573

SPOR VE SAĞLIK BİLİMLERİ

MAKALE İSMİ	YAZARLAR	SAYFA NO
GEÇİRİLMİŞ EKİNOKOKOSİS ENFESTASYONU KARSİNOM HÜCRELERİNİN BÜYÜMESİNİ BASKILAR MI? (DENEYSEL ÇALIŞMA)	SERHAT DOĞAN , MURAT ÇAKIR, ADİL KARTAL, HAYDAR ÖZTAŞ, PEMBE OLTULU, CENGİZ CEYLAN	585
GENTAMİSİNE BAĞLI OTO, NÖRO VE NEFROTOKSİSİTE, VAKA SUNUMU VE GÜNCEL LİTERATÜRE BAKIŞ	ENGİN ONAN	595
KRONİK HASTALIĞI OLMAYAN BİREYLERDE COVİD-19'UN ODYOLOJİK VE VESTİBÜLER BULGULAR AÇISINDAN İNCELENMESİ	DİDEM ŞAHİN CEYLAN, GÖKÇE GÜLTEKİN, YETER SAÇLI, BUSEMNAZ AVŞAR	601
DİŞ HEKİMLİĞİ FAKÜLTESİNE BAŞVURAN ÇOCUK HASTALARIN EBEVEYNLERİNİN KLİNİĞE YÖNELİK BAKIŞ AÇILARININ DEĞERLENDİRİLMESİ	AYŞE GÜNAY, ALPARSLAN MUSTAFA ÇELER	612
AKUT İZOLE VOLER DİSTAL RADİOULNAR EKLEM ÇIKIĞI : İLK AŞAMADA CERRAHİ Mİ KONSERVATİF Mİ?	HÜSEYİN UTKU ÖZDEŞ	621
MİKROBİYOLOJİK TANIDA YAPAY ZEKÂNIN ROLÜ: GÜNCEL GELİŞMELER VE İLERİYE DÖNÜK PERSPEKTİFLER	ERGİN KARACAN, CEBRAİL BURAN	629
GENÇLİK VE SPOR BAKANLIĞI BÜNYESİNDE ÇALIŞAN BRANŞ ANTRENÖRLERİNİN MESLEKİ TÜKENMİŞLİK DÜZEYLERİNİN İNCELENMESİ (ANKARA ÖRNEĞİ)	ÜLKÜ SİBEL ALTINSOY	637
DEMODEKTİK DONMUŞ KULAK: YENİ TANIMLANMIŞ ANTİTE EŞLİĞİNDE DEMODEKS PARAZİTLERİNİN DERMATOLOJİDEKİ YERİ	İLKAY CAN	650
İNDOSİPİSİN: ET TÜKETİMİ VE HALK SAĞLIĞI	ZEHRA AKINER, AHMET GÜNER	655
OKÜLER CERRAHİ GEÇİREN BARDET-BİEDL SENDROMU OLAN HASTADA ANESTEZİ DENEYİMİMİZ	MUSTAFA BÜYÜKCAVLAK	667
OTİZMLİ İKİ KARDEŞTE YENİ BİR USP9X VARYANTI: ÇOK NADİR GÖRÜLEN BİR X'E BAĞLI ENTELEKTÜEL GELİŞİM BOZUKLUĞU	HAMİDE BETÜL GERİK-ÇELEBİ	672
İNTESTİNAL İSKEMİ REPERFÜZYON HASARI YAPILAN RATLARDA PİNOCEMBRİN'İN KORUYUCU ETKİSİ	OSMAN BARDAKÇI, HAKİM ÇELİK, İLYAS ÖZARDALI, ALİ UZUNKÖY	675
HİPERTİROİDİDE VOXEL TABANLI MORFOMETRİ DEĞİŞİKLİKLERİ	BARIŞ GENÇ	685
INFRATENTORİAL TÜMÖRLÜ PEDİATRİK HASTALARDA SUBKORTİKAL DEĞİŞİKLİKLER	BARIŞ GENÇ	690
PAPÜLOSKUAMÖZ HASTALIKLAR: BİR GÖZ KAPAĞI HİKAYESİ	MEHMET ÇAĞLAR SOYSAL, GİZEM GÜRBOSTAN SOYSAL	695
ÖLÜM İLE SONUÇLANAN ARAKNOİD KİSTİ OLAN ÇOCUK HASTA	NAZİFE MENGİ	700

ÇOCUKLARDA GÖRÜLEN BİTKİ KAYNAKLI ZEHİRLENME VAKALARININ DEĞERLENDİRİLMESİ	ŞÜHEDA RUMEYSA OSMANLIOĞLU DAĞ	707
ARTEMİSİA L. TÜRLERİNİN ECZACILIKTAKİ YERİ VE ÖNEMİ	ŞÜHEDA RUMEYSA OSMANLIOĞLU DAĞ, AYŞE MİNE GENÇLER ÖZKAN	717

GÜZEL SANATLAR

MAKALE İSMİ	YAZARLAR	SAYFA NO
STUCKİZM: ÇAĞDAŞ SANATA KARŞI FİGÜRATİF RESMİN DİRİLİŞİ	HURİ KİRİŞ BÜYÜKGÜNER	730
ARTIRILMIŞ GERÇEKLİK UYGULAMALARININ TİPOGRAFİK TASARIMLARDA KULLANILMASI	ŞÜKRAN TARTAN	735
YARATICILIK VE DENEYSELLİK ARASINDA: JEL BASKI TEKNİĞİ	BUSE KIZILIRMAK ÇEKİNMEZ	738
TÜRK BASKIRESİM SANATÇILARININ BASKIRESİMLERİNDE KULLANDIKLARI HAYVAN İMGESİ	BUSE KIZILIRMAK ÇEKİNMEZ	749
FOTOĞRAFIN SANATTA VE KENDİ İÇİNDE YARATTIĞI DÖNÜŞÜM	COŞAR KULAKSIZ	759
BİR YÖNTEM OLARAK DİJİTAL GÖRSELLER OLUŞTURAN PETER GRİC'İN SANATININ İNCELENMESİ	YUSUF ŞENGÜR	765
ÇAĞDAŞ SANATTA NESNENİN GÖRÜNÜMÜ	ÇİĞDEM DOĞAN ÖZCAN	773
BİTKİSEL TABANLI BİR FOTOĞRAF BASKI TEKNİĞİ; ANTHOTYPE	MURAT HAN ER	783
TANITIM FOTOĞRAFI BAĞLAMINDA KOMPOZİT GÖRÜNTÜ	BASRİ GENÇCELEP	793

MİMARLIK VE TASARIM

MAKALE İSMİ	YAZARLAR	SAYFA NO
3 BOYUTLU (3D) YAZICI TEKNOLOJİSİNİN YAPI SEKTÖRÜNDE KULLANIMININ ÖRNEK YAPILAR ÜZERİNDEN İNCELENMESİ	ŞEVVAL KAPLAN, NİLAY COŞGUN	804
GELECEĞİN KENTLERİNDE YERALTI YAPILANMALARININ ÖNEMİ	SEDAT KAÇAN, SEMA KARAGÜLER	814
AVLULARIN SÜRDÜRÜLEBİLİRLİK AÇISINDAN DEĞERLENDİRİLMESİ VE YENİ BİR AVLU TİPOLOJİSİ	OYA BABALI TÜRKKAL, SEMA KARAGÜLER	827
HAZIR BETON ÜRETİM TESİSLERİNDE ÇEVRESEL ETKİLERİ AZALTICI YAKLAŞIMLARIN İNCELENMESİ	ZEYNEP TURAN, NİLAY COŞGUN	840
SUYUN ETKİN KULLANIMI KAPSAMINDA KURAKÇIL PEYZAJ UYGULAMALARININ ÖNEMİ	ZEHRA AYANOĞLU, KÜRŞAD DEMİREL	849
CBS VE UZAKTAN ALGILAMA KULLANILARAK ÇANAKKALE MERKEZİNDE BULUNAN PEYZAJ ALANLARININ DEĞİŞİMİNİN İNCELENMESİ	DENİZ YILDIRIM, KÜRŞAD DEMİREL	860
ÜNİVERSİTE KAMPÜSLERİNDE YERLEŞİM SİSTEMLERİNİN İNCELENMESİ	ZAFER KUYRUKÇU	867
KENTSEL MEKANDA MORFOLOJİK DEĞİŞİMLER: SANA'A, YEMEN ÖRNEĞİ	MURAT ÇAĞLAR BAYDOĞAN, ALİ ABDULKAFÌ AHMED ALI AL-ABSI	877

Opposition Learning based Single Candidate Optimizer for Clustering Problems

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Abstract

In this study, we propose a novel optimization algorithm called Opposition Learning based Single Candidate Optimization (OppSCO) by incorporating an opposition learning mechanism into the Single Candidate Optimization (SCO) algorithm. The performance of the two algorithms is evaluated on a clustering problem. The proposed OppSCO algorithm demonstrates superior convergence compared to the original SCO algorithm. Furthermore, the OppSCO algorithm is compared with classical heuristic optimization algorithms such as Genetic Algorithm (GA), Differential Evolution (DE), and Particle Swarm Optimization (PSO). The results indicate that the OppSCO algorithm outperforms the original SCO algorithm in terms of convergence and solution quality.

Keywords: Opposition Learning, Clustering, Metaheuristic, Optimization.

INTRODUCTION

Heuristic algorithms play a crucial role in solving complex problems by providing effective and flexible approaches. These algorithms draw inspiration from natural phenomena or social behaviors to optimize the objective function and find the best solution. Their application areas span across a wide range of fields, including engineering, business, artificial intelligence, and computer science. They can be divided into three types: evolution-based, swarm-based, and physics-based algorithms. Evolution-based algorithms are based on the principles of Darwinian natural selection and include the Genetic Algorithm (GA) (Kumar, 2010), Differential Evolution (DE) (Price, 2005), and others. Swarm-based algorithms are inspired by the collective behavior of swarms, and prominent examples include the Particle Swarm Optimization (PSO) (Kennedy, 1995), Artificial Bee Colony (ABC) (Karaboga, 2014), Cuckoo Search (CS) algorithm (Yang, 2014), Bat Algorithm (BA) (Yang, 2012), Ant Colony Optimization (ACO) (Dorigo, 2019), Firefly Algorithm (FA) (Johari, 2013), Salp Swarm Algorithm (SSA) (Mirjalili, 2017), Grey Wolf Optimization (GWO) (Mirjalili, 2014), and others. Physics-based algorithms emulate the laws of physics governing our universe and notable examples in this category include Simulated Annealing (SA) (Rutenbar, 1989), Electromagnetism-Like Search (EM) (Birbil, 2003), Gravitational Search Algorithm (GSA) (Rashedi, 2009) and many more.

The Single Candidate Optimization (SCO) algorithm offers a new strategy that differs from traditional heuristic search algorithms especially based on swarm-based methodologies (Shami, 2022). Unlike swarm or population-based heuristic algorithms, SCO exclusively utilizes a single candidate solution throughout the entire optimization process, aiming to achieve better solutions. The optimization process is divided into two phases, each with different approaches to update the position of the candidate solution. While single-solution-based algorithms and two-phase approaches have been established as separate meta-heuristic optimization methods, SCO integrates these concepts into a single, robust algorithm. A notable aspect of this algorithm is the implementation of a unique set of equations that update the candidate solution's position solely based on its own information, such as its current position. By combining these elements, SCO offers a novel and effective approach to optimization problems.

While the Single Candidate Optimization (SCO) algorithm offers several advantages, it is important to consider its potential disadvantages. SCO's reliance on a single candidate solution may limit its exploration capabilities. Without the diversity introduced by multiple candidates, SCO may struggle to explore the solution space effectively and may become trapped in local optima. It may be more prone to getting stuck in suboptimal regions of the search space and may struggle to find the global optimum. The performance of the SCO is also influenced by the position of the initial candidate solution. Finally, the SCO mechanism used in the exploration phase may cause the position of the candidate solution to go to zero point in a short time. This delays convergence in SCO performance for problems with non-zero solution points.

Opposition-based learning is a mechanism that enhances the optimization process by introducing the concept of opposition in candidate solutions (Tizhoosh, 2005). In this approach, the solutions are not only evaluated based on their original values but also their opposite counterparts. The opposite of a solution is obtained by negating the values of its components or by applying a specific transformation. The opposition-based learning mechanism aims to improve the exploration capability and convergence speed of optimization algorithms. By considering the opposite solutions, it introduces additional diversity into the search process. This diversity allows the algorithm to explore different regions of the search space simultaneously, potentially leading to a more comprehensive exploration and a higher chance of finding better solutions.

In this paper, in order to eliminate the disadvantages of the SCO algorithm and improve its search performance, we mainly integrate the opposition-based learning mechanism into the SCO algorithm. Thanks to the opposition-based learning mechanism, the SCO algorithm has the chance to start with a better opposite candidate solution at the beginning and has the chance to catch a better opposite solution than the updated candidate solution at the end of each iteration. To evaluate the performance of Opposition Learning based Single Candidate Optimization (OppSCO) algorithm, we considered a clustering problem with original SCO algorithm.

MATERIAL & METHODS

Single Candidate Optimization (SCO) Algorithm

The Single Candidate Optimization (SCO) algorithm represents a novel approach that sets itself apart from traditional searching algorithms by employing a single candidate solution exclusively throughout the entire optimization process. In contrast to swarm-based algorithms that utilize a collection of particles, SCO centers its focus on a solitary solution with the aim of attaining enhanced optimization outcomes. The optimization process in SCO is divided into two distinct phases, each characterized by a different approach to updating the position of the candidate solution. These distinct phases facilitate the application of different strategies and mechanisms, thereby increasing the algorithm's capacity for both exploration and exploitation. By combining the single-candidate approach with the two-phase strategy, SCO seeks to exploit the respective advantages of both methodologies.

During the initial phase of SCO, the candidate solution undergoes position updates according to the following procedure:

$$x(j) = \begin{cases} S(j) + (w|S(j)|), if\ r_1 < 0.5 \\ S(j) - (w|S(j)|), otherwise \end{cases} \quad (1)$$

$$w(i) = e^{-\left(\frac{b \cdot i}{i_{max}}\right)^b} \quad (2)$$

where $x(j)$ denotes the position of candidate solution, j represents the dimension, w is the weight parameter, $S(j)$ stands for the global best candidate during optimization process, b is the constant parameter, i denotes the iteration, i_{max} is the maximum iteration, and r_1 is the random number between 0 and 1. In the second phase of SCO, a comprehensive search is performed, starting with an extensive exploration of the vicinity of the best position acquired in the first phase. Subsequently, in the latter part of the second phase, the search space is narrowed down to allow a more concentrated focus on promising regions. The following diagram details the process by which the candidate solution updates its position in the second phase:

$$x(j) = \begin{cases} S(j) + \left(wr_2(ub(j) - lb(j))\right), if\ r_2 < 0.5 \\ S(j) - \left(wr_2(ub(j) - lb(j))\right), otherwise \end{cases} \quad (3)$$

where ub, lb denote the upper and lower boundary values of the search space, and r_2 represents the random number. A crucial aspect of SCO is the exponential decrease of the parameter w as the number of function evaluations increases. This adaptive behavior plays a vital role in balancing exploration and exploitation throughout the optimization process. By starting with a relatively high value of w, SCO effectively explores the search space, while gradually decreasing it promotes exploitation in the later stages. Furthermore, SCO addresses the challenge of being trapped in local optima by modifying the position update in the second phase. If m consecutive function evaluations do not yield fitness improvement, the candidate solution's position is adjusted according to the following procedure:

$$x(j) = \begin{cases} S(j) + \left(r_3(ub(j) - lb(j))\right), if\ r_3 < 0.5 \\ S(j) - \left(r_3(ub(j) - lb(j))\right), otherwise \end{cases} \quad (4)$$

where r_3 represents the random number. The position update equation (4) facilitates a transition from exploitation to exploration for the candidate solution, thereby aiding its escape from local optima. This shift in the position update mechanism enables the algorithm to explore alternative regions of the search space and avoid getting trapped in suboptimal solutions.

Opposition Learning based Single Candidate Optimization (OppSCO) Algorithm

Opposition Learning based Single Candidate Optimization (OppSCO) is a novel algorithm proposed in this study that integrates the concept of opposition learning into the Single Candidate Optimization (SCO) framework. The goal of OppSCO is to improve the convergence performance of

SCO by taking advantage of the benefits of opposition-based learning. In OppSCO, the candidate solution is evaluated not only on the basis of its original attributes, but also on the basis of its opposite counterparts, thus introducing additional diversity and exploration capabilities into the optimization process. By combining the strength of SCO's single-candidate approach with the opposition learning mechanism, offers a promising solution for improving convergence and solution quality in optimization problems. In general, OppSCO algorithm comprises two key steps: opposition-based population initialization and opposition-based generation jumping. These steps serve as fundamental components in OppSCO and contribute to its overall optimization process.

During the opposition-based population initialization phase, the candidates in the population are used to calculate opposition candidates. This process generates individuals that are considered more favorable than those assigned by random population initialization. By incorporating opposition-based techniques, the population initialization step improves the suitability of the assigned individuals for subsequent optimization procedures. This procedure is given below:

$$\breve{x}(j) = [ub(j) + lb(j)] - x(j) \tag{5}$$

where $\breve{x}$ stands for the opposite position of initial candidate. At the end of each iteration in the optimization process, an opponent candidate is determined based on a predefined jump probability value. Subsequently, superior candidates are selected from the combination of the current population and the opponent population for the next iteration. The execution of the opposition-based generation jump depends on the result of the comparison of the jump rate (Jr) with a random number in the range [0, 1], as illustrated in the expression below:

$$\breve{x}(i+1) = \begin{cases} ub + lb - x(i), if\ r_4 < Jr \\ x(i), otherwise \end{cases} \tag{6}$$

We also changed the update mechanism in the first phase of the original SCO algorithm as follows. K is a random number used in original SCO algorithm.

$$x(j) = \begin{cases} S(j) + (w|S(j)|K), if\ r_1 < 0.5 \\ S(j) - (w|S(j)|K), otherwise \end{cases} \tag{7}$$

EXPERIMENTAL RESULTS

In this section, we evaluated the performance of the proposed OppSCO algorithm by using the clustering problem. Clustering problem is a machine learning task that aims to group data points into distinct clusters based on a specific criterion or similarity measure. In the problem solution, the distances between data points and cluster centers are calculated and each data point is assigned to the nearest cluster. Then the sum of the intra-cluster distances is calculated, which shows how compact the clusters are. Clustering cost is the value of the sum of the intra-cluster distances. The cost function formula is given below:

$$J = \sum_{i=1}^{N} min_j \left\| x_i - c_j \right\|^2 \tag{8}$$

where J is the cost value, x_i denotes the case i, c_j represents the centroid for cluster j, N is the number of cases. In this study, we used a clustering dataset consisting of 300 two-dimensional data.

The dataset was taken from Yarpiz website (Heris, 2015), and is shown in Fig.1. First, the results obtained by the original SCO and the proposed OppSCO algorithms are compared for the three clusters. Fig. 2 shows the convergence curves of the original SCO and the proposed OppSCO algorithms. As can be seen from this figure, the OppSCO algorithm has better performance than the SCO algorithm. Thanks to the opposition-based learning mechanism, the proposed OppSCO algorithm shows a better convergence in solving the clustering problem. In Fig. 3, the clustering results of both algorithms are shown. Looking at the results obtained for the three clusters, it is clear that the centroids obtained with OppSCO are more successful than those obtained with SCO.

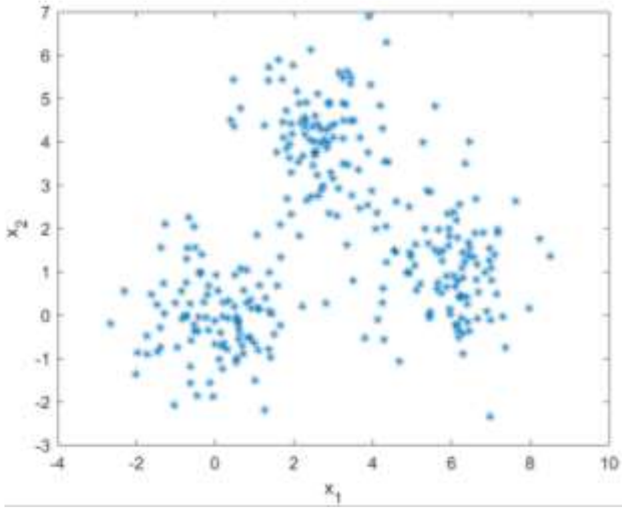


Figure 1. *Clustering data (Heris, 2015) used in this study.*

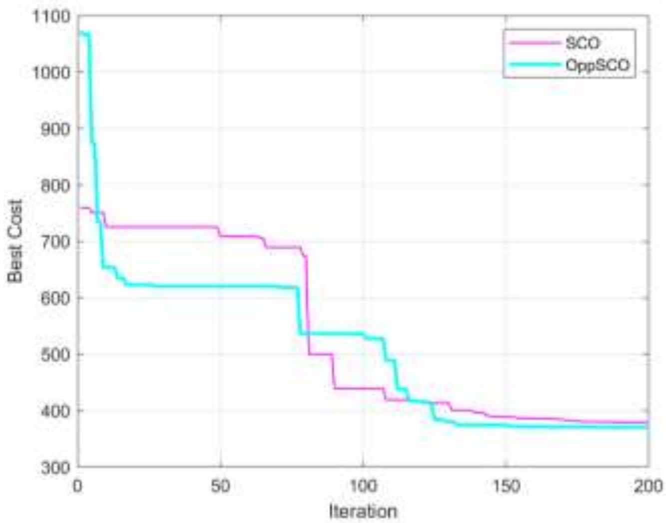
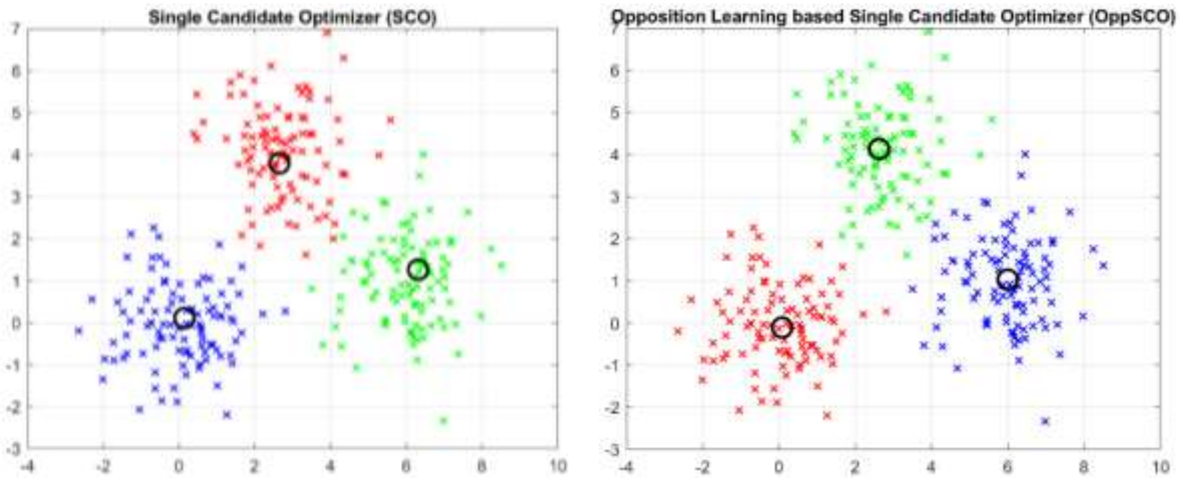


Figure 2. *Convergence Curves of SCO and OppSCO*



(a) (b)

Figure 3. *Results of SCO (a) and OppSCO (b)*

In the other test, we compared the OppSCO algorithm with the popular heuristic algorithms. These algorithms are Genetic Algorithm (GA), Differential Evolution (DE) and Particle Swarm Optimization (PSO). The codes and parameters of the GA, PSO, and DE algorithms are taken from Yarpiz website (Heris, 2015). For the comparison test, the number of clusters is set to five. The statistical results of the five iteration optimizations are summarized in Table 1. In this table, there are four metrics, namely, max, min, mean, and standard deviation (STD). The results show that the OppSCO algorithm has the third best value in the minimum metric and the best result belongs to GA. The maximum metric results show that OppSCO has better performance than SCO algorithm. In the mean metric values, GA algorithm is in the first place and OppSCO result is better than SCO. In the standard deviation results, it is understood that the original SCO algorithm has the highest deviation value. Finally, we analyzed the running times of the algorithms for repeated runs. Table 2 shows the statistical results of the running times. From the results, the great advantage of the single candidate solution approach in the OppSCO and SCO mechanism is clearly seen.

Table 1. *Statistical results of OppSCO and other heuristics*

	GA	**PSO**	**DE**	**SCO**	**OppSCO**
MIN	311.6968	316.0045	317.2864	323.7386	316.3898
MAX	312.6416	316.0064	320.6813	348.1509	338.1013
MEAN	311.9643	316.0056	319.2246	336.5650	329.2956
STD	0.3887	0.0010	1.3591	10.1035	8.4751

Table 2. *Run time results of OppSCO and other heuristics*

	GA	PSO	DE	SCO	OppSCO
MIN	4.2917	5.0511	5.1029	0.0865	0.1058
MAX	5.4334	5.7265	5.7248	0.0954	0.1276
MEAN	5.0801	5.2809	5.3448	0.0912	0.1175
STD	0.4648	0.2599	0.2459	0.0032	0.0090

RESULTS

In this study, the Single Candidate Optimization (SCO) algorithm, which was introduced to the literature in 2022, is considered and it is aimed to increase the performance of the algorithm by integrating the opposition learning mechanism into this algorithm, namely Opposition Learning based Single Candidate Optimization (OppSCO). We evaluated the performance of the proposed OppSCO algorithm for the solution of the clustering problem. For our evaluation, we utilized a clustering dataset consisting of 300 two-dimensional data points obtained from the Yarpiz website.

In addition to comparing OppSCO with SCO, we conducted further tests to compare the OppSCO algorithm with popular heuristic algorithms, namely, Genetic Algorithm (GA), Differential Evolution (DE), and Particle Swarm Optimization (PSO). The statistical results of the five iteration optimizations indicate that the OppSCO algorithm achieved the third-best value in the minimum metric, with GA yielding the best result. In terms of the maximum metric, OppSCO exhibited better performance than the SCO algorithm. Considering the mean metric values, the GA algorithm secured the first place, and OppSCO outperformed SCO. The standard deviation results revealed that the original SCO algorithm had the highest deviation value. Furthermore, we analyzed the running times of the algorithms for repeated runs, and the statistical results. The results highlight the significant advantage of the single candidate solution approach employed in the OppSCO and SCO mechanisms.

In conclusion, our evaluation of the OppSCO algorithm for the clustering problem showed its superior performance over the original SCO algorithm. The opposition-based learning mechanism in OppSCO contributed to improved convergence and more successful clustering results. Furthermore, OppSCO demonstrated competitive performance against popular heuristic algorithms such as GA, DE and PSO on various metrics. The OppSCO algorithm, with its efficient running times and remarkable results, emerges as a promising approach to clustering problems.

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