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BÖLÜM 1

Metin Özetlemede Ekstraktif ve Abstraktif Yaklaşımlar

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GİRİŞ

Metin özetleme, bulunduğumuz dijital çağda verinin ve bilginin giderek daha da büyüyen ve çeşitlenen önemli araştırma alanlarından biri haline gelmiştir. Dünya üzerinde her gün milyarlarca haber, e-posta, blog yazısı, sosyal medya paylaşımı ve akademik makale gibi çeşitli alanlarda ve mecralarda gönderi yayınlandığını göz önüne alırsak, bu yoğun bilgi akışının, yeni teknolojilerin ve farklı yöntemlerin keşfedilmesini zorunlu kıldığı söylenilebilir. İşte tam bu noktada, araştırmacılar metin özetleme üzerinde daha kısa, net ve anlaşılır özetler elde etmeye yönelik çalışmalarda bulunmuşlardır. Metin özetleme, hem geçmişte hem de günümüzde yapay zeka ve doğal dil işleme çalışmalarının önemli bir parçası haline gelmiştir. Özellikle "ekstraktif" ve "abstraktif" olmak üzere iki ana yaklaşım üzerinden şekillenen bu alan, araştırmacılara çok çeşitli yöntem ve teknik yelpaze sunmaktadır. Bazı kaynaklarda bu iki ana yaklaşımı sırasıyla "çıkarımsal (ekstraktif)" ve "soyut özetleme (abstraktif)" olarak görmek de mümkündür. Metin özetlemenin üzerindeki akademik araştırmalar ilk kez 1950'li yıllarda kullanılan ve işleme kapasitelerinin son derece sınırlı olduğu bilinen bilgisayarların kullanıldığı yıllara kadar uzanmaktadır. O dönemde bilim insanları, teknolojinin henüz emekleme döneminde olmasına rağmen insan aklını taklit etmek için uzun metinlerin nasıl kısaltılabileceğini sorguluyorlardı. Bunun başlıca sebebi, kütüphanelerde veya akademik dokümanların bulunduğu arşivlerde biriken bilgi yığınlarının özetlenerek araştırmacılara, karar vericilere veya meraklı okurlara daha hızlı sunulması ihtiyacıydı. İnsanın sezgisel olarak yaptığı özetleme davranışının makinelere nasıl öğretilebileceği sorusu, dönemin en ilgi çekici araştırma başlıklarından biri olarak görülüyordu. O dönemlerde bilgisayarlar, günümüzde kullandığımız bilgisayarlara göre gerek donanım gerekse yazılımsal anlamda çok geride olmasına rağmen araştırmacılar basit istatistiksel yöntemlere başvurarak metnin içerisinde bulunan kelimelerin frekanslarını alarak kelime sıklığı üzerinden önemli kelimeleri tespit etmek ve ardından bu kelimelerin bulunduğu cümleleri seçme işlemleri, ekstraktif özetleme yaklaşımının temelini oluşturmuştur. Bunun sonucunda araştırmacılar makalelerin özetlerini elde etmeye çalışıyorlar ve manşet niteliğindeki cümleleri yakalamayı umuyorlardı. Böylece, metnin tamamını okumadan özetlenmiş bilgiyle hızlı bilgi erişimi sağlayarak zamanlarını daha verimli kullanarak daha derinlemesine araştırmalar yapabileceklerdi. İlerleyen dönemlerde anlamsal ağlar (semantic networks) ve sözlük tabanlı yöntemler, metin içeriklerini anlamlandırma konusunda yeni ufuklar açmıştır. Dilbilim ilkelerinin bilgisayar algoritmalarına uyarlanması, özetleme sürecini frekans gibi basit istatistiksel yöntemlerin daha da ötesine taşımıştır. Anlamsal ağlar, konu cümlelerinin tanımlanması (topic sentences) ve cümlelerin birbirleriyle olan ilişkileri, özetleme algoritmalarının kalitesini artırmaya yönelik önemli adımlardan biriydi. Bu yıllarda, ekstraktif yöntemler ağırlıklı olarak ilgi görmüştü. Çünkü orijinal metinden seçilen cümleleri kısaltmak ya da aynen almak, o dönemin teknik eksiklikleri ve kısıtları yüzünden daha uygulanabilir ve daha az hata alınabilecek bir yolmuş gibi kabul edilmekteydi. 1980'li ve 1990'lı yıllarda yapay zekâ ve makine öğrenmesi tekniklerinin gelişmesi, metin özetlemeye ilişkin daha sofistike yaklaşımların belirlenmesine sahne olmuştur. Özellikle makine öğrenmesi tabanlı puanlama yöntemleri ve istatistiksel modellemeler, metindeki her cümlenin farklı özelliklerini değerlendirerek en önemli cümleleri seçmeye yönelik algoritmalar sunmaya başladı (Kupiec, Pedersen & Chen, 1995). Örneğin cümle içinde bulunan anahtar kelime sayısı, kelimelerin bulunduğu cümlelerin dilsel bilgiye göre anlamsal yapısı veya cümlenin geçtiği konum gibi kriterler, ekstraktif özetleme süreçlerinde önem sıralaması yapmaya yardımcı oluyordu. Yine bu yıllarda akademik ve kurumsal ortamlarda özetleme sistemlerine duyulan ihtiyaç artarken, henüz insan benzeri özet çıkarımı yapabilecek sistemlerin ortaya çıkması oldukça güç görünüyordu. 2000'li yıllara girdiğimizde, internet kullanımının daha yaygın olmaya başlaması, devasa boyutlara ulaşan veri kümelerine erişimi kolaylaştırdı ve bu sayede haber sitelerinden, dijital kütüphaneler platformlarından alınan metin veri setleri üzerinde daha ayrıntılı çalışmalar yapılabilir oldu. Paralel olarak bilgisayarların işlem güçlerinin artması ve daha kolay erişilebilir olması da bu çalışmaları destekledi. Bu gelişmeler sonrasında metindeki anlam bütünlüğünü ya da bağlamı daha iyi kavrayabilen doğal dil işleme modelleri sadece kelime saymak veya belirli yer işaretlerini (örneğin başlıklar, alt başlıklar vb.) analiz etmekle kalmıyor; metnin anlamsal bileşenlerini, konular arası geçişleri ve dilsel bilgiyi de göz önünde bulundurabiliyordu (Mani & Mayburty, 1999). 2010'lu yılların ortalarından itibaren, metin özetleme için derin öğrenme alanında gerçekleştirilen çığır açıcı çalışmalar bir dönüm noktası oluşturdu. Önceden eğitilmiş dil modelleri, kelimelerin ve cümlelerin anlamsal karşılıklarını yüksek boyutlu vektörler halinde temsil etmeye olanak tanıyarak, özetleme algoritmalarına çok daha derin bir anlama kapasitesi getirdi (Rush et al., 2015). Bu dönemde, tekrarlayan sinir ağları (RNN), uzun kısa süreli bellek (LTSM) ve kapılı tekrarlayan birim (GRU) gibi mimariler, ardıl bilgi akışını takip edebilme özellikleri sayesinden metnin semantik bağlamını koruyarak özet üretmeyi başardılar. Takip eden süreçte, transformer tabanlı modellerin ortaya çıkışı, metin özetlemeyi daha da ileriye taşıdı. Transformer mimarisi, çok katmanlı dikkat mekanizmaları kullanarak uzun metinlerdeki bağıntıları daha etkili bir şekilde yakalayabilmekteydi (Vaswani et al., 2017). Bu gelişme, BERT gibi modellerin dil anlama ve metin işleme görevlerinde üstün başarı göstermesine zemin hazırladı (Devlin, Chang, Lee & Toutanova, 2019). Ardından önceden eğitilmiş üretken dönüştürücü (GPT – Generative Pre-trained Transformer) ailesiyle birlikte, büyük veri setleri üzerinden önceden eğitilen ve soyut metin oluşturma kabiliyeti yüksek olan modeller, özetleme görevine de entegre edildi. Bu modeller, metin özetlemede sadece orijinal cümleleri seçmekle kalmayıp, içerdikleri ileri dil üretimi yetenekleri sayesinde insan benzeri yeni cümleler üretebilmektedir (See, Liu & Manning, 2017). Böylece, abstraktif özetlemenin önündeki teknik engeller bu modeller sayesinde önemli ölçüde azaltılmıştır.

O halde bu iki ana yaklaşım üzerinde daha detaylı olarak inceleme yapmadan önce kısa bir değerlendirme yapalım. Ekstraktif özetlemede amaç, metnin içinden olduğu gibi veya çok küçük düzeltmelerle bazı cümle veya kelime gruplarını seçip özetleme yapma işlemidir. Bu yöntem, kaynağa yüksek oranda sadık kaldığı için genellikle tercih edilen ve uygulaması daha basit bir yöntem olarak görülmüştür. Ancak, ekstraktif yöntemin ortaya çıkardığı özetlerin okuyucuyu tam anlamıyla yönlendirebilecek bütüncül bir yapı sunması her zaman mümkün olmayabilir. Çünkü metin içerisinden alınan farklı cümlelerin bir araya getirildiğinde akışta kopukluk ve tekrar gibi problemler doğması söz konusudur (Edmundson, 1969). Öte yandan abstraktif özetleme daha insan merkezli bir yaklaşım sunar. İnsanlar bir metni özetlerken, orijinal cümleleri olduğu gibi aktarım yapmak yerine o cümlelerin anlamsal olarak özünü kavrayarak yeniden oluşturur. Abstraktif özetleme de bu prensibe dayanarak metnin ana fikrini kavrayıp kendi cümlelerini oluşturmasını hedefler. Bu sayede tekrarlar azaltılır, metnin anlamı korunur ve daha akıcı bir özet elde edilebilir. Tabii ki bunun bir karşılığı olaraktan önemli ölçüde dil işleme becerisine sahip olmak, büyük veri setine ve yüksek işlem gücüne ihtiyaç duyar. Sonuç olarak baktığınızda sinir ağı (neural network) ve derin öğrenme (deep learning) temelli algoritmaların yükselişiyle birlikte, abstraktif özetlemenin uygulanabilirliği ve başarısı gözle görülür derecede artmıştır (Rush, Chopra & Weston, 2015; Chopra, Auli & Rush, 2016).

TEMEL KAVRAMLAR VE MATEMATİKSEL MODELLER

TF-IDF ve Kelime Ağırlıklandırmasının Temelleri

TF-IDF, metin içerisindeki kelimelerin bilgi taşıma değerlerini sayısal vektör olarak tanımlayan temel yöntemlerden biridir. Terim frekansı, belirli bir kelimenin metin içerisinde kaç kez geçtiğini hesaplar. Ters belge frekansı ise kelimenin tüm belge kümesindeki yaygınlığını değerlendirir. Bu sayede, frekansı daha yüksek olan kelimeler öne çıkarılır. Bu algoritmanın matematiksel ifadesi aşağıdaki şekilde ifade edilir:

$$\text{TF-IDF}(t, d) = \text{TF}(t, d) \times \log\left(\frac{N}{DF(t)}\right) \qquad (1)$$

Burada, TF(t,d) kelimenin metin belgesi içerisindeki frekansını, DF(t) ise kelimenin geçtiği belge sayısını ve N' de toplam belge sayısını temsil eder. Bu yöntem, metin özetlemede cümlelerin ağırlıklandırılması için kritik bir rol oynar. Çünkü TF-IDF değeri hesaplanmış cümleler, metnin en önemli bilgilerini içermektedir (Manning Raghavan & Schütze, 2008).

Kosinüs Benzerliği ve Çizge Tabanlı Yöntemler

Kosinüs benzerliği, iki TF-IDF vektörü arasındaki ilişkisel açı benzerliği ölçerek, cümleler arasındaki anlamsal yakınlığı değerlendirir. Bu algoritmanın matematiksel ifadesi aşağıdaki şekilde ifade edilir:

$$\cos(\theta) = \frac{\vec{A} \cdot \vec{B}}{|\vec{A}||\vec{B}|} \qquad (2)$$

Bu ölçüm sonucunda TextRank ve LexRank gibi çizge tabanlı algoritmaların temel yapı taşları belirlenir. Bu algoritmalar cümleler arasındaki benzerlik matrisini gözlemleyerek metin içerisindeki merkezi cümleleri belirler. TextRank algoritması PageRank algoritmasına benzer olarak metin içerisindeki cümlelerin önemini hesaplayarak özet oluşturur. Bu işlem sonucunda metin içerisindeki en kritik bilgileri içeren cümleleri öne çıkartır (Mihalcea & Tarau, 2004; Erkan & Radev, 2004).

Transformer Mimarisi ve Derin Öğrenme Yaklaşımları

Transformer algoritmasının mimarisi, dil modellemede çığır açan bir yapıdır. Encoder-decoder yapısı sayesinde, girdi bilgilerini paralel olarak işleyerek önemli bilgileri öne çıkarmada kullanılır. Self-attention mekanizması sayesinde her bir token arasındaki ilişkinin belirlenmesini sağlayarak, hangi bilginin daha önemli olduğuna karar vermede kullanılır. Bu özellikleri sayesinde abstraktif özetlemede model metnin semantik içeriğinin yeniden yorumlanmasını ve özgün cümlelerin üretilmesini sağlar. BART, mBART ve T5 gibi modeller bu yapıyı kullanarak diğer modellere göre daha yüksek performans ile özetler üretmektedir (Vaswani et al., 2017; Lewis et al., 2020).

EKSTRAKTİF ÖZETLEME ALGORİTMASI

Ekstraktif özetleme, metnin öz yapısını koruyarak en önemli cümleleri bulma ve bunların bir araya getirerek özetleme yapılması prensibine dayanmaktadır.

Veri Toplama ve Ön İşleme

Metin özetlemede kullanılacak verinin kalitesi hesaplamalar ve yapılacak olan çıkarımlar için büyük önem arz etmektedir. Çünkü hesaplamada kullanılacak olan veri, haber arşivleri, akademik makaleler ve diğer kaynaklardan temin edilir. Bu aşamada, verinin toplanması, okunması ve temizleme işlemleri şu şekilde gerçekleştirilir:

Dosya Okuma ve Kodlama

Metinler, dosya formatlarına (.txt, .pdf, .docx vb.) uygun olarak okunmaktadır. UTF-8 kodlaması kullanılarak karakter uyumsuzlukları minimuma indirgenir. Bu adım, verinin doğru bir biçimde ele alınabilmesi için temel bir gerekliliktir.

Veri Temizleme İşlemleri

Metin içerisindeki çeşitli dosya formatı etiketleri, kontrol karakterleri, özel semboller ve yanlış veya fazla kullanılan boşluklar düzenli ifadeler (regex) yardımıyla temizlenir. Bu işlem, özellikle TF-IDF'in hesaplama doğruluğunu arttırmak ve dil yapısının korunmasını sağlamak için kritik bir öneme sahiptir.

Cümle Ayırma

Temizleme işlemi tamamlanan metin verisi, noktalama işaretleri ve işlemin uygulandığı dilin dilbilgisel kurallarına göre cümlelere ayrılır. Bu adım, algoritmanın uygulanabilmesi ve metnin anlamsal bütünlüğü bozmayacak şekilde gerçekleştirilir.

Bu adımlar, metin verisinden elde edilen cümlelerin kaliteli ve tutarlı olmasını sağlayarak sonraki adımlarda elde edilecek özetlerin doğruluğunu ve anlamlılığını güvence altına alır (Manning, Raghavan & Schütze, 2008).

Vektörleştirme, Benzerlik Hesaplamaları ve Çizge Yapılandırması

Özetlemede, her bir cümlenin temsil edilmesi ve elde edilen diğer cümlelerle olan ilişkilerinin ölçülmesi için uygulanan temel adımlardan biridir.

TF-IDF Hesaplaması

Her cümlenin kelime dağılımı üzerinden TF-IDF değerleri hesaplanır. Elde edilen değerler, cümlede bulunan kelimelerin bilgi değerinin sayısal bir temsilidir. Yüksek TF-IDF değerine sahip cümlenin metin içerisindeki önem düzeyini arttırır.

Kosinüs Benzerliği

Bu ölçüm, iki cümle arasındaki anlam benzerliğini ortaya çıkartır ve 0 ile 1 arasında bir değer ataması gerçekleştirir. Benzerlik değeri 1' e yakın olan cümleler arasındaki güçlü anlamsal ilişkiyi temsil ettiği gibi, 0' a yakın olan cümleler arasındaki ilişkinin zayıf anlamsal ilişkileri olduğuna işaret eder.

Çizge Yapılandırması

Benzerlik matrisi, cümleler arasındaki ilişkiyi grafik yapısına dönüştürür. Her cümle bir düğüm olarak temsil edilirken, kenar ağırlıkları cümleler arasındaki kosinüs benzerliği değerine göre atanır.

- **TextRank Uygulaması:**

TextRank algoritması, grafikteki düğümlerin ağırlıklarını hesapladıktan sonra en merkezi ve dolayısıyla en önemli cümleleri belirler. Belirlenen cümleler, metnin ana fikrini en iyi yansıtan ifadeler olarak özetin temel bileşenlerini oluşturur.

- **LexRank Alternatifi:**

Benzer prensipler üzerinden cümlelerin merkeziyetine göre özet oluşturulmasını sağlar.

Bu işlem sonrasında metnin en kritik cümlelerin sayısal ve grafiksel analizle seçilmesini sağlayarak, elde edilen özetin hem anlamsal bütünlüğünün hem de dil yapısı üzerinde tutarlılığını arttırır (Mihalcea & Tarau, 2004; Erkan & Radev, 2004).

Chunklama ve İkinci Aşama Özetleme

Büyük veri içeren metinlerde, tüm metin üzerinde tek seferde işlem yapılması zaman ve bilgisayar donanımı açısından verimsizlik yaratacağından ötürü metin parçalar halinde işlenir:

- **Chunklama**

Uzun metin verilerinde dil modellerinin işlem kapasitesine daha uygun biçimde parçalara ayrılması sonucunda zamanı verimli kullanma ve işlem gücü için gerekli donanımı daha uygun boyutlara indirgenmesinde verimli bir yöntemdir. Bu işlemde, metin önce "token" adı verilen en küçük işleme birimlerine bölünmesi sağlanır. Token, genellikle bir kelime veya noktalama işaretini ifade eder. Örneğin, Devlin ve arkadaşlarının (2018) çalışmasında geliştirilen BERT modelinde maksimum chunk limitini 512 token olarak sınırlandırılmıştı. Bu durumda, 3000 token içeren bir metin verisini 3000/512 işlemiyle yaklaşık 6 parçaya ayrılması anlamına geliyordu. Ancak, Jurafsky ve Martin (2020)' de belirttiği üzere, yalnızca matematiksel bölünme yapmak metnin anlamsal bütünlüğünün korunacağını garanti altına alınamayacağını belirtmişti. Çünkü cümle, paragraf gibi doğal dil sınırları göz ardı edildiğinde anlam kaybı yaşanmasına sebep olur. Bu nedenle, chunklama yapılırken metnin içerdiği dilin yapısal özelliklerini de dikkate alarak metni doğal kesim noktalarına göre bölünmeli ve gerektiğinde ardışık parçalar arasındaki anlam bütünlülüğünü korumak için örtüşme (overlap) uygulanmalıdır.

- **Ara Özetleme**

Her bir chunk üzerinde ayrı olarak TextRank işlemi yapılır ve elde edilen bu chunk'ların her biri için ara özet elde edilir. Bu işlem sonucunda önem düzeyi en yüksek olan yani en önemli olan cümleler tespit edilir.

- **Nihai Özetin Oluşturulması**

Ara özetleme sonucunda elde edilen ara özetler, tekrar birleştirilerek, yeni bir özetleme işlemi uygulandıktan sonra nihai özet oluşturulur. Bu iki aşamalı yaklaşım, uzun metinlerde olası bilgi kaybını en aza indirgeyerek özetin bütünlüğünü korur.

Bu süreç, özellikle büyük ölçekli veri setlerinde daha verimli sonuçlar elde etmek ve hesaplama maliyetlerini düşürebilmek için çok büyük bir öneme sahiptir (Nenkova & McKeown, 2011).

ABSTRAKTİF ÖZETLEME ALGORİTMASI

Abstraktif özetleme, metnin semantik yapısını daha derinlemesine analiz ederek, orijinal metinde bulunmayan yeni cümleler üretme prensibine dayanır. Bu yöntem, Transformer tabanlı modellerin kullanılmasıyla uygulanır.

Veri Ön İşleme ve Tokenizasyon

Ekstraktif özetlemedeki gibi abstraktif özetlemede de ön işleme adımları aynıdır. Bu iki metin özetleme yaklaşımı için metnin yazıldığı dilin dilsel örüntülerini mümkün olduğunca koruyarak temizleme işlemi yapılır.

Tokenizasyon

Metin, Transformer modelinin anlayabileceği dilsel birimlere yani tokenlara ayrılır. Bu adımda:

- Kelime öbekleri, noktalama işaretleri ve dilin diğer yapısal özellikleri doğru bir şekilde korunarak ele alınır.

– Modelin girdi limiti (genellikle 512 token) göz önünde bulundurularak, metin parçalara bölünür.

Bu süreç modelin daha doğru bir şekilde girdiyi işleyebilmesi ve yüksek kaliteye sahip özetler üretebilmesi için temel bir gerekliliktir.

Model Seçimi ve Kurulumu

BART, mBART veya T5 gibi önceden eğitilmiş modeller, geniş veri setleri üzerinde ince ayar yani fine-tuning yapılarak kullanılmaktadır. Bu modellerin seçim aşamasında öne çıkan önem olarak özetleme görevinde yüksek performans ve verimlilik sağlama amacı taşır.

Encoder-Decoder Yapısı

Modelin encoder kısmı, girdideki tüm bilgileri paralel olarak işlerken, decoder kısmı bu bilgileri kullanarak yeni özet cümlelerini üretir. Dil yapısının semantik özelliklerini yeniden yapılandırmak için kritik bir rol oynar.

Self-Attention Mekanizması

Model, girdide ayrılan tüm tokenlar arasındaki ilişkiyi hesaplayarak, hangi bilginin öne çıkartılması gerektiği bilgisine karar verir. Bu mekanizma, özellikle daha uzun metin verisi içeren metinlerde semantik yapının derinliğini yakalamada kritik öneme sahiptir.

Hiperparametre Ayarları ve Optimizasyon

Modelin eğitim sürecinde, modelin performansını artırmak amacıyla ışın arama (beam search), uzunluk cezası (length penalty) ve tekrar etmeyen n-gram (no-repeat n-gram) gibi hiperparametre ayarları dikkatlice optimize edilmesi gerekmektedir.

- **Işın Arama**

Özet üretimi sırasında her adımda birden fazla aday oluşturur ve en yüksek olasılığa yani modelin mevcut kelime dizisi veya bağlamı temel alarak bir sonraki kelime için hesapladığı ve o kelimenin doğru veya uygun olma derecesini ifade eden değere sahip olan cümlelerin değerlendirilmesini sağlar (See, Liu & Manning, 2017; Holtzman et al., 2020). Sonuç olarak dilsel tutarlılık, akıcılık ve bağlam bütünlüğü üzerinde iyileştirmeler yapması iyi olmasına rağmen hesaplama maliyeti artışına neden olabilir.

- **Uzunluk Cezası**

Modelin çok kısa veya çok uzun olması durumunda uzun özetler üretilmesini engellemek amacıyla, kısıtlanan uzunluğu aşan durumlarda oluşturulan özetlere ceza uygulanır ve özetin istenen uzunlukla kalması sağlanır.

- **Tekrarlamayan n-gram Kısıtlaması**

Üretilen özet içerisinde aynı n-gram dizilerinin tekrarlanmasını önlemek amacıyla getirilen bu kısıtlama, dilsel akıcılığı ve özgünlüğü destekler.

Bu hiperparametre optimizasyon teknikleri, modelin aşırı öğrenme (overfitting) veya dengesizlik gibi problemlere karşı daha dayanıklı hale gelmesini sağlar ve eğitim sürecinde yapılan detaylı ayarlamalar, özetlerin kalitesinde belirgin artışlar elde edilmesine katkıda bulunur (See et al., 2017; Holtzman et al., 2020).

UYGULAMA

EkstraktifYaklaşımı Özetleme Uygulaması

Metin Veri Seti

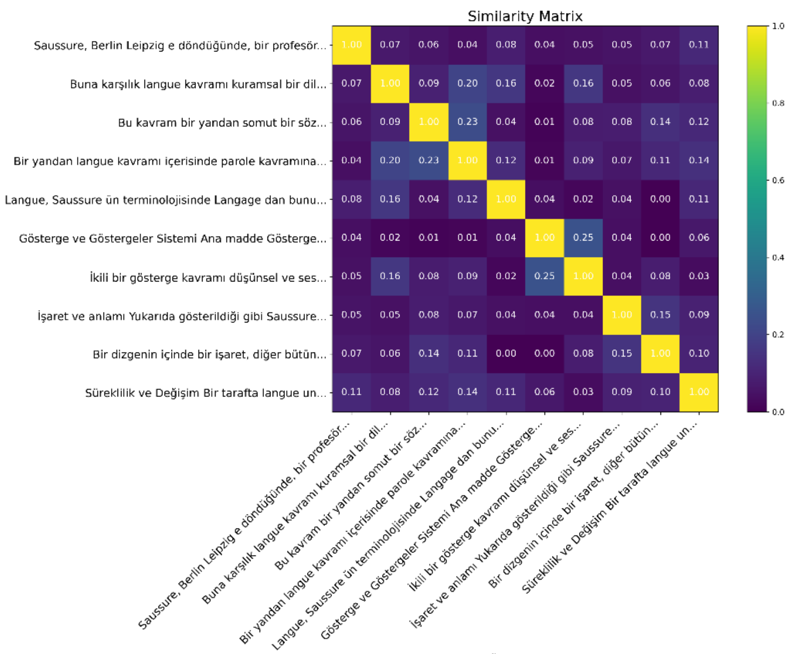
Bu uygulama için açık kaynak olan Wikipedia' dan elde edilen İsviçreli Dilbilimci Ferdinand de Saussure biyografi metni alınmıştır. Wikipedia, Saussure'ün yaşamı, eğitimi ve dilbilime katkıları konusunda zengin bilgiler sunmaktadır.

Ekstraktif Yaklaşımı Özetleme Algoritması

Bu uygulamada temizlenmiş metin cümlelere ayrılarak, her cümle için TF-IDF temelli vektörleştirme ve benzerlik hesaplamaları gerçekleştirilmiştir. Daha sonra, TextRank algoritması ile cümleler arasındaki anlamsal ilişkiler değerlendirilmiş ve her chunk içerisinde en önemli üç cümle seçilmiştir. Tüm chunk'ların ara özetleri arasından da nihai özet oluşturulması amacıyla en kritik on cümle belirlenmiştir.

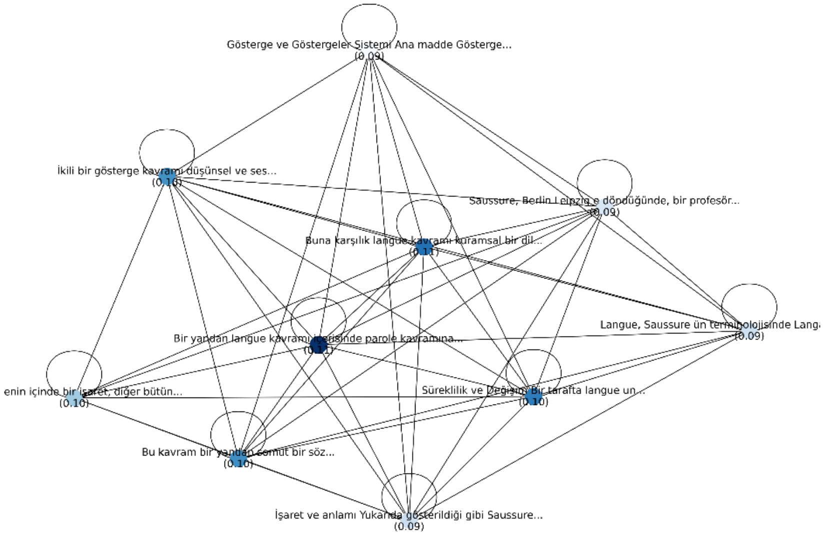
- Chunk Boyutu = 35
- Metin, 35 token'lik parçalara bölünerek modelin girdi limiti içinde uygun parçalara ayrıldı.
- Blok Başına Seçilecek Özet Cümle Sayısı = 3
- Her bir chunk içerisinde hesaplanan TF-IDF derecelendirilmesinde en yüksek orana sahip 3 cümle seçildi.

- Nihai Özet için Seçilecek Toplam Cümle Sayısı = 10
- Tüm chunk’lardan elde edilen ara özet cümleleri arasından özet oluşturulması amacıyla 10 cümle belirlenir.
- Tolerans = 0.1
- Benzerlik hesaplamalarında esneklik sağlamak amacıyla algoritmanın cümleler arasındaki küçük farkları göz ardı etmesi sağlandı.



Şekil 1

Şekil 1 de verilen benzerlik matrisinden görüldüğü üzere karar aşamalarının bir kısmı için eşik değeri verilmiş olup cümleler arasındaki benzerlikler 35 cümlelik bloklar üzerinden hesaplanan matriste benzerlik oranları belirlenmiş, yüksek ilişkiye sahip olan ve birbirine benzerlik gösteren cümle yapıları ortaya konulmuştur.



Şekil 2

Şekil 2' de 35 cümlelik chunk'lar içinde seçilen ara özet cümlelerin arasındaki bağlantılar, düğüm etiketleri ile önem dereceleri görselleştirilmiştir. Bu sayede, algoritmanın hangi cümleleri merkezi kabul ettiğini açıkça göstermektedir.

Ekstraktif Yaklaşım Özet Sonucu:

Temizlenmiş Metin (İlk 500 karakter):

"Ferdinand de Saussure 26 Kasım 1857, Cenevre 22 Şubat 1913, Vufflens le Château, 20. yüzyılda dilbilimde kayda değer gelişiminin birçoğu için fikirleriyle temel hazırlamış, İsviçreli dilbilimci. Genellikle 20. yüzyılın dilbiliminin babası olarak düşünülmektedir. Özellikle yapısalcılık ve göstergebilim alanında adını duyurmuştur. Ferdinand, doğabilimci Henri de Saussure ve Louise Elisabeth de Pourtalès in oğlu ve Nicolas Theodore de Saussure ün torunudur. Ferdinand Almanya nın Leipzig şehrinde üniversite eğitimi almıştır ve Berlin de bir dönem Heinrich Zimmer in yanında Hint Avrupa Dilleri üzerine çalışmıştır. Leipzig de doktorasını yazdıktan sonra 1881 yılından 1891 yılına kadar Paris te École pratique des hautes études okulunda ders vermiştir. 1891 yılından ölümüne kadar Cenova Üniversitesi nde tarih ve Hint Avrupa dillerinin karşılaştırılması alanında profesörlük yapmıştır. Ferdinand de Saussure, Cenova Üniversitesi nde 1906 yılından 1911 yılına kadar Genel dilbilim üzerine dersler vermiştir. Saussure ün şöhreti yaşamı boyunca Slav dilleri araştırmacısı olarak yaptığı

çalışmalarında mevcuttur. Mémoire sur le système primitif des voyelles dans les langues indo européennes Memory auf dem primitiven System der Vokale im Indo Europäischen Sprachen Hint Avrupa Dillerindeki Seslerin İlkel Sisteminin Hafızası 1879 isimli eserinde Saussure daha 21 yaşında bir öğrenciyken dilbilgisel yöntemleri uygulayarak Laringeal kuramını geliştirmiştir. Hint Avrupa ses sisteminin yeniden yapılandırılması sürecinde Saussure kaybolan ses katsayılarının coefficients sonantiques varlığını kuramsal olarak talep etmektedir. Bu ses katsayılarını daha sonraları Danimarkalı dil araştırmacısı Hermann Møller de 19. yüzyılda Laringeal olarak tanımlamıştır. Saussure ün ölümünden sonra 1914 yılında Bedřich Hrozný bu noktada Hint Avrupa dili olarak belirtilen Hititçe yi çözümlemiştir. Sausure ün kendi ses katsayılarını yeniden yapılandırdığı bazı durumlarda Polonyalı dilbilimci ve Slav dilleri ...”

Nihai Özet:

“Saussure, Berlin Leipzig e döndüğünde, bir profesör ona İnceleme nin yazarı, İsviçreli büyük dil bilimci Saussure ile uzak yakın bir akrabalığı olup olmadığını sordu. Buna karşılık langue kavramı kuramsal bir dil kavramı olarak anlaşılmaktadır. Bu kavram bir yandan somut bir söz eylem kuramını konuşma yetisini ifade ederken diğer taraftan da her bir konuşan aracılığıyla langue kavramının bireysel olarak gerçekleştirilmesini ifade etmektedir. Bir yandan langue kavramı içerisinde parole kavramına dair hiçbir şey bulunmazken diğer yandan da parole kavramının her bir sosyal üretim sayesinde langue olarak adlandırılması mümkündür. Langue, Saussure ün terminolojisinde Langage dan bunu ya langue ve parole ün üst başlığı olarak ya da insan ve hayvanın dil yetisinin ayrılmasında kullanılan faculté de langage, yani dil kullanma becerisi olarak dil den ayrılmalı. Gösterge ve Göstergeler Sistemi Ana madde Gösterge iletişim Saussure, dilsel göstergeleri, anlamları ilişkilendirilen ses birimleri olarak kavramaktadır. İkili bir gösterge kavramı düşünsel ve ses bilimsel tarafını bağımsız, özgür düşünülebilir gösterge bölümleri olarak bir araya getirmektedir. İşaret ve anlamı Yukarıda gösterildiği gibi Saussure e göre anlam mantıklı olarak olması gereken işaret bireşiminden başka bir şey değildir, aksine somut olarak sosyal değişimde, işaret bireşiminde ortaya çıkarılmaktadır. Bir dizgenin içinde bir işaret, diğer bütün işaretlerden ayrılmaktadır. Süreklilik ve Değişim Bir tarafta langue un bireysel söz dağarcığı olarak öznel ve sosyal karakteri, diğer yanda bireysellikten uzak dil kullanım alışkanlıklarının sistemi ve bunun kendini diyalog biçiminde anlam gelişen yer olarak parole nin içinde sağlamlaştırmasından, Saussure tarafından belirlenen dilin zaman içindeki yaşam prensipleri sonucu çıkmaktadır.”

Abstraktif Yaklaşımı Özetleme Uygulaması

Bu yaklaşımda da temizlenmiş metin önce cümlelere ayrılarak Transformer tabanlı bir model olan mBART kullanılarak işlendi. Model ve tokenize Hugging Face Hub üzerinden 'facebook/mbart-large-50-many-to-many-mmt' olarak çekilmiştir. Bu model, Mbart-50 ailesine ait olup, çok dilli özetleme yeteneğine sahiptir ve Türkçe dil üretimine uygun şekilde yapılandırılmıştır. Model, girdide yer alan metni dilsel ve anlamsal bütünlüğü göz önünde bulundurarak yeniden yapılandırıp, orijinal metinde bulunmayan özgün cümlelerde üretmektedir. Temizlenen metin, modelin işlem kapasitesine uygun olacak şekilde chunk token limiti 100 olarak belirlendi ve 100 token'lik parçalara ayrıldı. Her chunk üzerinde modelin Türkçe dil yapısına uygun olması için başlangıç sembolü olarak 250023 parametresini uygulayarak dil yapısına uygun olması sağlandı. Daha sonra üretilen nihai özetin belirlenmesi için özet uzunluğunu 500 token ile sınırlandırarak modelin üreteceği özette akıcılığı ve tutarlılığı optimize edilmiştir.

- Işın Arama = 4
- Işın arama algoritmasında her adımda en olası 4 aday cümle tutulur. Bu yöntem, arama alanını genişleterek daha kaliteli ve tutarlı özet oluşturulması için çıktı kalitesi ile hesaplama maliyeti arasında denge kurulması hedeflenmiştir.
- Uzunluk Cezası = 2.0
- Üretilen özetin uzunluğunu kontrol etme amacıyla kullandığımız bu parametre 2.0 değeri ile modelin uzun ve gereksiz ifadeler içeren cümleler üretmesini önler ve daha öz ve anlaşılır özet elde etmemizi sağlar.
- Tekrarlamayan n-gram Kısıtlaması = 2
- Çıktı metni içerisinde aynı iki kelimelik (2-gram) dizilerinin tekrarlanmasını kısıtlamamız sonucunda özetin dilsel akıcılığı ve özgünlüğünü artırmak için 2 olarak belirlenmiştir.
- Minimum Uzunluk = 10
- Modelin üreteceği özetin en az 10 token uzunluğunda olmasını zorunlu kılarak nihai özetin çok kısa veya yetersiz bilgi içeren bir biçimde üretilmesi engellenmiştir.
- Chunk Token Limiti = 100

- Modelin işlem kapasitesine uygun şekilde 100 token'lik parçalara bölünmüş ve özellikle transformer tabanlı modellerin girdi uzunluğu limitlerini aşmaması ve bellek kullanımını optimize etmek amacıyla belirlenmiştir.
- Chunk Özet Uzunluğu = 500
- Her bir chunk için üretilen özetin maksimum uzunluğunu 500 token ile sınırlandırarak nihai özetin gereğinden uzun veya detaylı ifadeler içermesi engellendi.
- Zorunlu Başlangıç Sembolü = 250023
- Modelin çıktı üretimine başlarken zorunlu olarak kullanılacak başlangıç (BOS– beginning of sequence) token'ini belirledik. 250023 değeri, Türkçe dil koduna karşılık gelmektedir. Böylece modelin ürettiği özetin Türkçe dil yapısına uygun olması sağlanmıştır.

Metrik Sonuçlar:

- Chunk 1: Token aralığı [0:100]- Chunk token sayısı: 100, Özet token sayısı 91, Özet karakter uzunluğu: 383
- Chunk 2: Token aralığı [100:200]- Chunk token sayısı: 100, Özet token sayısı 70, Özet karakter uzunluğu: 333
- Chunk 3: Token aralığı [200:300]- Chunk token sayısı: 100, Özet token sayısı 97, Özet karakter uzunluğu: 386
- Chunk 4: Token aralığı [300:400]- Chunk token sayısı: 100, Özet token sayısı 87, Özet karakter uzunluğu: 345
- Chunk 5: Token aralığı [400:428]- Chunk token sayısı: 28, Özet token sayısı 15, Özet karakter uzunluğu: 62

Abstraktif Yaklaşım Özet Sonucu:

Temizlenmiş Metin (ilk 500 karakter):

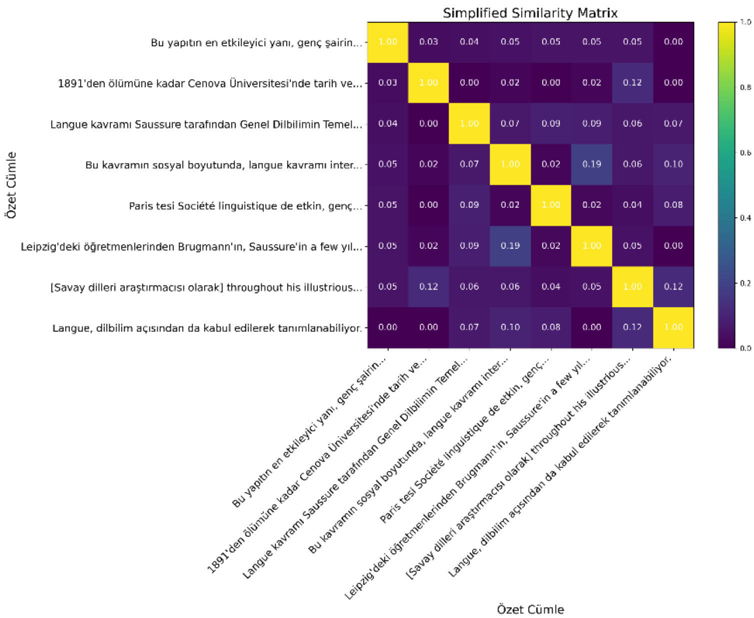
"Ferdinand de Saussure 26 Kasım 1857, Cenevre 22 Şubat 1913, Vufflens le Château, 20. yüzyılda dilbilimde kayda değer gelişiminin birçoğu için fikirleriyle temel hazırlamış, İsviçreli dilbilimci. Genellikle 20. yüzyılın dilbiliminin babası olarak düşünülmektedir. Özellikle yapısalcılık ve göstergebilim alanında adını duyurmuştur. Ferdinand, doğabilimci Henri de Saussure ve Louise Elisabeth de Pourtalès in oğlu ve Nicolas Theodore de Saussure ün torunudur. Ferdinand Almanya nın Leipzig şehrinde üniversite eğitimi almıştır ve Berlin de bir dönem

Heinrich Zimmer in yanında Hint Avrupa Dilleri üzerine çalışmıştır. Leipzig de doktorasını yazdıktan sonra 1881 yılından 1891 yılına kadar Paris te École pratique des hautes études okulunda ders vermiştir. 1891 yılından ölümüne kadar Cenova Üniversitesi nde tarih ve Hint Avrupa dillerinin karşılaştırılması alanında profesörlük yapmıştır. Ferdinand de Saussure, Cenova Üniversitesi nde 1906 yılından 1911 yılına kadar Genel dilbilim üzerine dersler vermiştir. Saussure ün şöhreti yaşamı boyunca Slav dilleri araştırmacısı olarak yaptığı çalışmalarında mevcuttur. Mémoire sur le système primitif des voyelles dans les langues indo européennes Memory auf dem primitiven System der Vokale im Indo Europäischen Sprachen Hint Avrupa Dillerindeki Seslerin İlkel Sisteminin Hafızası 1879 isimli eserinde Saussure daha 21 yaşında bir öğrenciyken dilbilgisel yöntemleri uygulayarak Laringeal kuramını geliştirmiştir. Hint Avrupa ses sisteminin yeniden yapılandırılması sürecinde Saussure kaybolan ses katsayılarının coefficients sonantiques varlığını kuramsal olarak talep etmektedir. Bu ses katsayılarını daha sonraları Danimarkalı dil araştırmacısı Hermann Møller de 19. yüzyılda Laringeal olarak tanımlamıştır. Saussure ün ölümünden sonra 1914 yılında Bedřich Hrozný bu noktada Hint Avrupa dili olarak belirtilen Hititçe yi çözümlemiştir. Sausure ün kendi ses katsayılarını yeniden yapılandırdığı bazı durumlarda Polonyalı dilbilimci ve Slav dilleri …"

Nihai Özet:

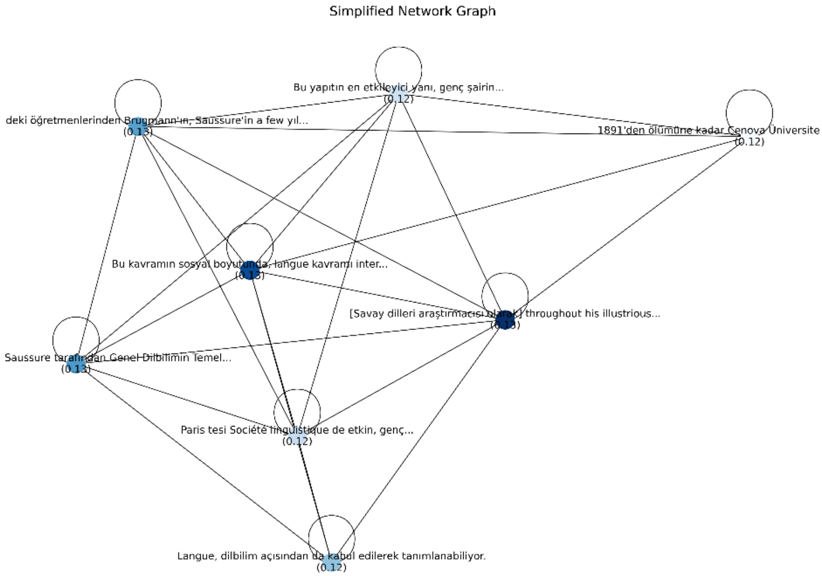
"Bu yapıtın en etkileyici yanı, genç şairin tarihsel dil biliminde en büyük ve en temel sorunu ele alması ve yöntemsel sorunların önemini vurguladı. 1891'den ölümüne kadar Cenova Üniversitesi'nde tarih ve Hint Avrupa dillerinin karşılaştırması alanında profesörlik yapmıştır. Langue kavramı Saussure tarafından Genel Dilbilimin Temel Sorunları Cours de linguistique générale, 1916 dt. Bu kavramın sosyal boyutunda, langue kavramı inter özneler kabul edilen bir toplumsal kurum ve dil alışkanlıkları sosyal olarak oluşturan, bir konuşmac'ın kafasında geleneksel bir sistem. Paris tesi Société linguistique de etkin, genç Fransız dil bilimci kuşunun formlanmasına da önemli katkıda bulundu. Leipzig'deki öğretmenlerinden Brugmann'ın, Saussure'in a few yıl önce öne sürdüğü, fakat ünlü şairlerin varsayımlarına karşı düştüğü genisel hallucinalar, nasal sonans yasası'nın dediği bir şeyi bulduğunda, kendi becerileri şüphesiz onaylandı.Bu hareket genelde konuşanlar tarafından algılanmıyor.Hasta geleneği izleyerek fizik ve kimya öğrencisi olmakla birlikte, Yunan ve Latin dil bilgisi derslerine girmeye devam Bu conceptler, Saussure için bir sayfa kâğıt (bir sayfanın ön yüzü), sound için de arka yüzü [dur.] [Savay dilleri araştırmacısı olarak] throughout his illustrious lifetime, Ferdinand de Sasur, Cenova Üniversitesi'nde 1906-1911 yılları arasında Genel dilbilim

dersleri vermişti ve bu deneyimi, onun mesleki dil incelemesi açısından taşıyacaktır. Langue, dilbilim açısından da kabul edilerek tanımlanabiliyor."



Şekil 3

Şekil 3'de yüksek benzerlik değerleri, cümleler arası yoğun anlamsal bağlantıyı göstermektedir. Bu durum modelin cümleler arasındaki anlamsal ilişkiyi yakalama yeteneğini göstermektedir.



Şekil 4

Şekil 4' de gösterildiği gibi, her düğüm özetin bir cümlesini temsil ederken, etiketlerde cümlenin kısaltılmış hali ve önem dereceleri görülmektedir. Bu grafik, modelin ürettiği cümlelerin merkezileşmesini ve yapısal bütünlüğünü göstermektedir.

SONUÇLAR

Her iki özetleme yöntemi de, metnin temel yapısal ve anlamsal özelliklerini yansıtmada başarılı olmuştur. Ancak yöntemlerin yaklaşım farklılıkları, nihai özetlerin doğasında belirgin farklılıklar göstermiştir. Ekstraktif özetleme, metnin orijinal ifadesine bağlı kalarak bilgi yoğunluğunu doğrudan yansıtırken, abstraktif özetlemenin ise daha özgün ve akıcı ifadeler sunmasına rağmen modelin üretkenlik kapasitesine bağlı olarak orijinal metinden sapma riski taşıdığı sonucuna varılmaktadır. Bu sonuçlar, ilgili literatürdeki çalışmalar (Mihalcea & Tarau, 2004; Rush et al., 2015; See et al., 2017) ile uyumlu olup, yöntemlerin uygulamadaki etkililiği ve sınırlamalarını detaylı olarak ortaya koymaktadır. Kullanılan metrikler ve grafiksel analizler, her iki yöntemin performansını sayısal ve görsel olarak ayrıca ortaya koymakta olup yaklaşımların avantajları ve kısıtlamaları hakkında detaylı değerlendirme yapma imkânı sağlamaktadır.

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BÖLÜM 2

Benchmarking U-Net, FCN, and DeepLabV3 for Precision Plant Segmentation in Agricultural Applications

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INTRODUCTION

The agricultural sector is facing increasing challenges due to the dual pressures of a rapidly growing global population and the escalating scarcity of natural resources. These pressures necessitate innovative and sustainable practices to meet rising food production needs while preserving environmental integrity (Allioui & Mourdi, 2023). Among emerging technologies, plant segmentation has garnered significant attention due to its potential to revolutionize precision agriculture by enabling efficient crop monitoring, early disease detection, and yield optimisation (Bruno et al., 2022; Hughes & Salathé, 2015).Through the accurate delineation of plant structures in imagery, plant segmentation serves as a foundational technology for the development of automated agricultural systems and robotic applications.

The field of plant segmentation has been profoundly influenced by deep learning, which has led to the development of architectures such as U-Net, Fully Convolutional Networks (FCN), and DeepLabV3, which have achieved remarkable success in a variety of image segmentation tasks.U-Net, initially developed for biomedical imaging, has been shown to excel in integrating local and global features through its encoder-decoder structure and skip connections, making it highly effective for detailed segmentation tasks (Ronneberger et al., 2015). Conversely, FCN, with its fully convolutional framework, offers flexibility and efficiency across diverse segmentation problems, though it struggles with finer details (Long et al., 2015). DeepLabV3 incorporates atrous convolutions to capture multi-scale contextual information, demonstrating robust performance in challenging scenarios (Chen et al., 2017). For instance, while U-Net has been the subject of extensive research in the context of biomedical segmentation tasks (Smith et al., 2020), its application in agricultural datasets, such as PlantVillage, remains under-explored. This underscores the necessity for comparative analyses tailored to agricultural contexts, where unique challenges, including diverse plant morphologies and environmental variability, exist.

In order to address this research gap, the present study conducts a rigorous comparative evaluation of U-Net, FCN, and DeepLabV3 using the PlantVillage dataset. The latter is a comprehensive collection of over 54,000 images encompassing 38 plant species and their associated diseases (Hughes & Salathé, 2015). The study systematically benchmarks these architectures to identify their strengths and limitations in the context of plant segmentation, providing valuable insights for advancing precision agriculture.U-Net's ability to accurately segment plant structures holds potential for real-time monitoring systems in greenhouse environments, enabling targeted interventions and resource optimisation.This analysis highlights U-Net's superior performance and underscores the critical role of architecture selection in developing efficient AI-driven agricultural systems. The overarching objective of this research is to leverage artificial intelligence to enhance agricultural productivity and sustainability (Bruno et al., 2022; Allioui & Mourdi, 2023).

Related Works

In recent years, deep learning techniques have emerged as effective and efficient alternatives for the detection of plant diseases. These techniques employ a range of architectures and methodologies for the classification, segmentation and analysis of images obtained from plant leaves. This review examines six articles that employ deep learning techniques for plant disease detection and utilise segmentation methods. A notable study, which employs deep learning techniques for the detection of tomato leaf diseases, is published in the literature. The authors of this study compared various Convolutional Neural Network (CNN) architectures for the classification of leaf images, selecting the model with the optimal performance. Furthermore, the U-Net architecture was employed for leaf image segmentation, and image augmentation techniques were utilised to enhance the segmentation outcomes. The study demonstrated that deep learning techniques offer a high degree of accuracy in detecting tomato leaf diseases (Ashok et al., 2020). In the study, a new segmentation method for plant disease diagnosis was proposed, in which the authors utilised a colour space transformation and an edge detection algorithm to segment leaf images. The authors claimed that their proposed method yielded superior results in comparison to traditional segmentation methods and could be used with deep learning models (Gurrala et al., 2019). In a subsequent study, the performance of CNN models with deep learning for the detection of plant diseases was analysed, with different CNN architectures being tested for leaf image classification and the model with the best performance being determined (Gurrala et al., 2019). The U-Net architecture was also employed for leaf image segmentation, and the segmentation results were evaluated. The study concluded that deep learning CNN models provide high accuracy, sensitivity, and F score in plant disease detection (Sharma et al., 2020).

A substantial corpus of literature has emerged in recent years on the application of deep learning methodologies in the domain of plant disease detection and classification.This study undertakes a comprehensive review of the extant literature, offering a detailed and comparative analysis of deep learning architectures, datasets, performance metrics and application scenarios for plant disease detection. The study emphasised the pivotal role of deep learning in plant disease detection, while concurrently highlighting the challenges that still need to be addressed, including issues of data quality, model complexity, computational costs and generalisation capability (Li et al., 2021).Additionally, a study on the segmentation of roots buried in the soil using the U-Net architecture involved the acquisition of root images through X-ray tomography. The images were then subjected to a series of preprocessing, magnification and normalisation stages, after which it was demonstrated that the U-Net architecture provides segmentation success with high accuracy, precision and F-score values.These findings enable further research on topics such as plant growth and stress response (Smith et al., 2020).In another study, improvements were made to the traditional U-Net architecture with the aim of facilitating the segmentation of diseased regions in plant leaves. The authors enhanced the model's learning capability and segmentation quality by incorporating an attention mechanism and a dense link block within the U-Net architecture.The proposed model demonstrated superior performance in comparison to both the traditional U-Net and other existing segmentation models, thus providing an effective method for plant disease detection (Zhang and Zhang, 2023).

The U-Net architecture, recognised for its efficacy in biomedical image segmentation, achieved a noteworthy 92.03% IOU on the ISBI Challenge Dataset (Ronneberger et al., 2015). In a similar vein, DeepLab, with its semantic segmentation capabilities, attained a mean IOU of 79.7% on the PASCAL VOC 2012 dataset (Chen et al., 2017). Mask R-CNN, developed for instance segmentation, demonstrated a 37.1% mask AP on the COCO Dataset (He et al., 2017). The FCN, with its emphasis on semantic segmentation, achieved a 65.3% mIOU on the PASCAL VOC 2011 dataset (Long et al., 2015). The PSPNet, utilising the technique of pyramid scene parsing, secured an 85.4% mIOU on the Cityscapes Dataset (Zhao et al., 2017). Finally, UNet++, a nested U-Net architecture for medical image segmentation, demonstrated an impressive 92.4% Dice Score on the BraTS Dataset (Zhou et al., 2018). These references collectively contribute to the diverse landscape of image segmentation methodologies, providing valuable insights for researchers and practitioners alike.

MATERIAL AND METHODS

Dataset

The PlantVillage dataset (Hughes & Salathé, 2015) was utilised in this study, comprising 54,303 high-quality images of healthy and diseased leaves from 38 plant species. The dataset's diversity, including images captured under varying environmental conditions, provides an ideal foundation for testing model generalisation. The data set was segmented into training (70%), validation (15%), and testing (15%) subsets. All images were resized and standardized to conform to the input dimensions of the models. Examples of dataset are provided in Figure 1.

Figure 1. Dataset Examples

Training Parameters and Data Augmentation

The models were trained using the Adam optimiser (β1 = 0.9, β2 = 0.999, ϵ = 1e-8,

β1 = 0. 9,β 2 =0.999,ϵ=1e −8) with an initial learning rate of 0.001, reduced to 0.0001 every 10 epochs based on validation loss.A batch size of 32 was used, and training was conducted over 30 epochs without early stopping. Data augmentation techniques comprised random rotations (angles: 0°, 90°, 180°, 270°), flipping (horizontal and vertical), scaling (10–20%), and brightness/contrast adjustments (15% probability).Training and validation performance metrics were monitored and visualised after each epoch to prevent overfitting. Figure 2 provides a visualisation of images and predictions using Deeplab v3, while Figure 3 presents an example of an image and mask from the dataset.

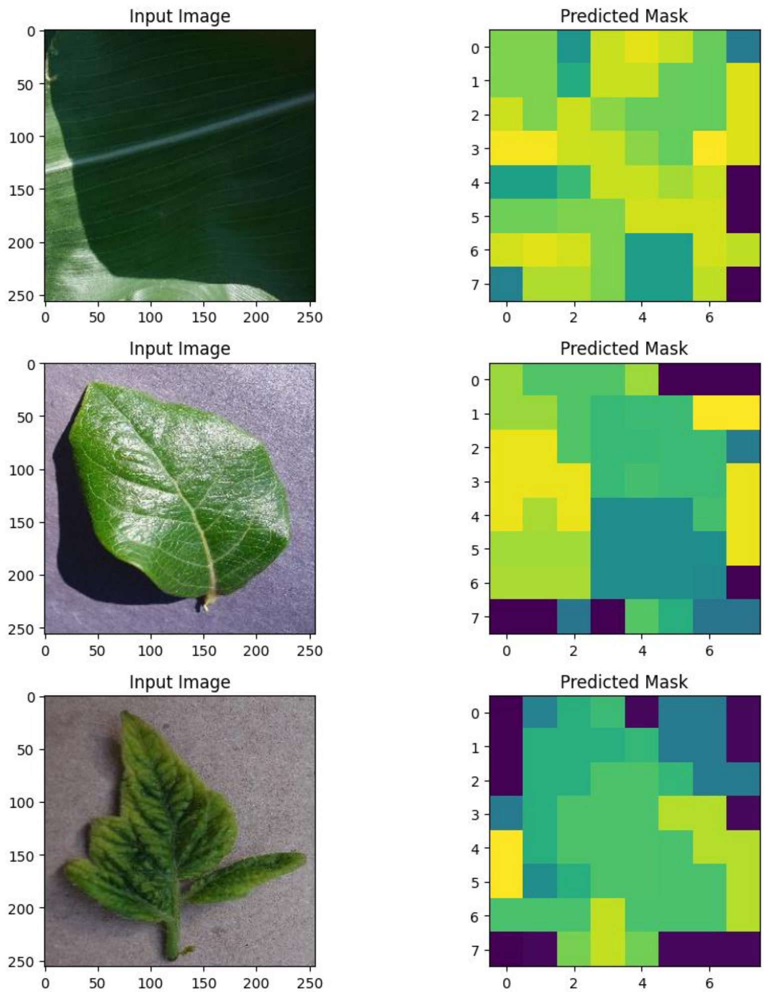


Figure 2. Deeplab v3 Visualising images and predictions

Figure 3. Example of an image and mask from the dataset

Network Architectures

1. U-Net

U-Net architecture (Ronneberger et al., 2015) was employed for binary classification (healthy vs. diseased) of 32×32×3 leaf images. It features a contracting path (downsampling via 3×3 convolutions and 2×2 max pooling) and an expanding path (upsampling with transposed convolutions) that fuses high-resolution features from the contracting path. We used mean squared error as the loss function and accuracy as the performance metric. The model achieved a 91.18% validation accuracy, demonstrating robust performance in distinguishing healthy leaves from diseased ones.

2. Fully Convolutional Network (FCN)

Based on the architecture proposed by Long et al. (2015), our FCN operates on 32×32×3 inputs and outputs class probabilities for 38 distinct categories. It comprises multiple convolution blocks (3×3 convolutions + 2×2 max pooling) followed by dense layers. Categorical cross-entropy served as the loss function, with accuracy as the metric. Dropout (50%) was used in the fully connected section to reduce overfitting. The FCN reached a 77.02% validation accuracy, indicative of moderate success for multi-class leaf disease classification.

3. DeepLabV3

Leveraging the DeepLabV3 framework (Chen et al., 2017) with atrous convolutions for broader context capture, we adapted an ImageNet-pretrained backbone (Russakovsky et al., 2015) and replaced the final layers to output 38 class probabilities. Input images were resized to 256×256×3. We employed sparse categorical cross-entropy as the loss function and accuracy as the performance metric. This model attained a validation accuracy of 81.26%, underscoring its strong capability in classifying diverse plant leaf images.

RESULTS AND DISCUSSION

U-Net model showed the highest performance in all metrics with 91.18% accuracy and 77.20% IoU value. The success of U-Net can be attributed to the encoder-decoder structure learning local and contextual information effectively and skip connections preserving fine details in the segmentation mask (Ronneberger et al., 2015). Especially, its ability to correctly distinguish complex plant morphologies in PlantVillage dataset shows the potential of this architecture in agricultural applications. FCN fell behind U-Net with 77.02% accuracy and 60.35% IoU. The low performance of FCN can be attributed to the limitation of its fully convolutional structure in separating small and complex plant structures. Long et al. (2015) stated that this structure is generally more suitable for large-scale and distinct objects. DeepLabV3 exhibited a balanced performance with 81.26% accuracy and 68.10% IoU. Atrous convolution modules effectively learned extensive contextual information, contributing to this success (Chen et al., 2017). In the present study, the performances of U-Net, FCN and DeepLabV3 architectures on the PlantVillage dataset were examined in detail. The models were compared with various metrics, including accuracy, precision, recall, F1 score and IoU. The ensuing performance results are presented in Table 1. This table provides a comprehensive comparison of the performance of various segmentation architectures utilised on different datasets. In the context of plant segmentation, U-Net stands out with its high IoU value.

Table 1. Comparison of Segmentation Architectures Across Various Dataset

Study	**Architecture**	**Performance Metric**	**Dataset**	**Referances**
U-Net: Convolutional Networks for Biomedical Image Segmentation	U-Net	%92.03 IOU	ISBI Challenge Dataset	Ronneberger et al., 2015
DeepLab: Semantic Image Segmentation with Deep Convolutional Nets, Atrous Convolution, and Fully Connected CRFs	DeepLab	%79.7 mean IOU	PASCAL VOC 2012	Chen et al., 2017
Mask R-CNN	Mask R-CNN	%37.1 mask AP	COCO Dataset	He et al., 2017

FCN: Fully Convolutional Networks for Semantic Segmentation	FCN	%65.3 mIOU	PASCAL VOC 2011	Long et al., 2015
PSPNet: Pyramid Scene Parsing Network	PSPNet	%85.4 mIOU	Cityscapes Dataset	Zhao et al., 2017
UNet++: A Nested U-Net Architecture for Medical Image Segmentation	UNet++	%92.4 Dice Score	BraTS Dataset	Zhou et al., 2018

The findings of this study lend support to the hypothesis that U-Net demonstrates superior performance in segmentation tasks, as evidenced in the extant literature. Ronneberger et al. (2015) demonstrated that U-Net provides precise segmentation in biomedical images, and Zhang and Zhang (2023) reported that a modified version of U-Net achieved 92.4% accuracy in plant segmentation. The present study also validated the success of U-Net in the context of the PlantVillage dataset.

The poor performance of FCN reflects the limitations mentioned in the literature, with Long et al. (2015) emphasising the loss of detail in segmentation masks and Sharma et al. (2020) showing that FCN is inadequate in separating plant structures.DeepLabV3's ability to learn contextual information is parallel to the findings of Chen et al. (2017). However, the fact that this model is not as successful as U-Net in fine details indicates that atrous convolutions limit the capacity to learn fine details (Dosovitskiy et al., 2020).U-Net's segmentation accuracy can be used for real-time disease detection and crop monitoring in agricultural robots (Smith et al., 2020).DeepLabV3 can be effective in mapping large agricultural areas with its ability to learn broad context. The FCN's low computational cost offers a lightweight and efficient option for mobile devices.Experiments can be conducted with more diverse datasets outside of PlantVillage (e.g. images from different climate conditions).New methods such as Vision Transformers and Segment Anything Model should be investigated, especially for their effectiveness on complex plant structures (Dosovitskiy et al., 2020). As illustrated in Figures 4 and 5, the outputs of Unet-Deeplab and Fcn are presented for three distinct models, respectively.

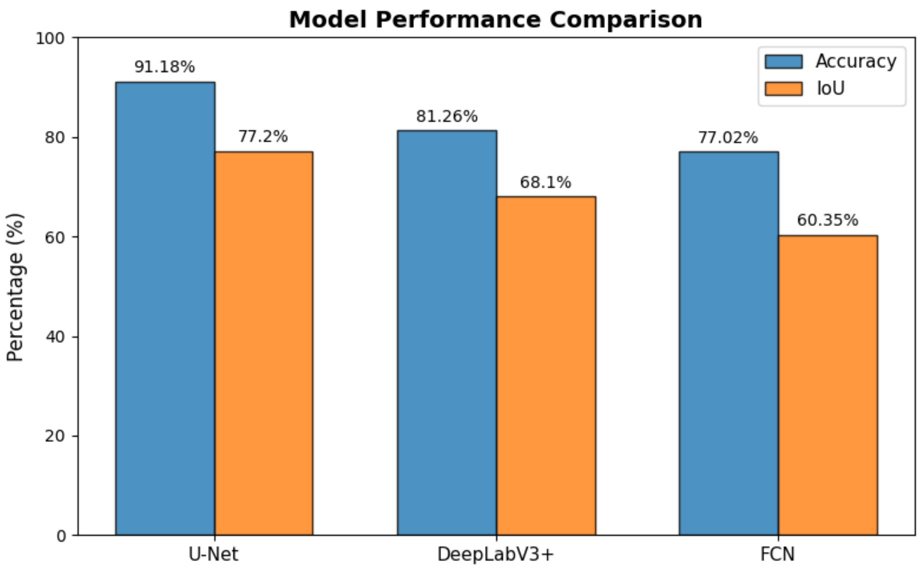
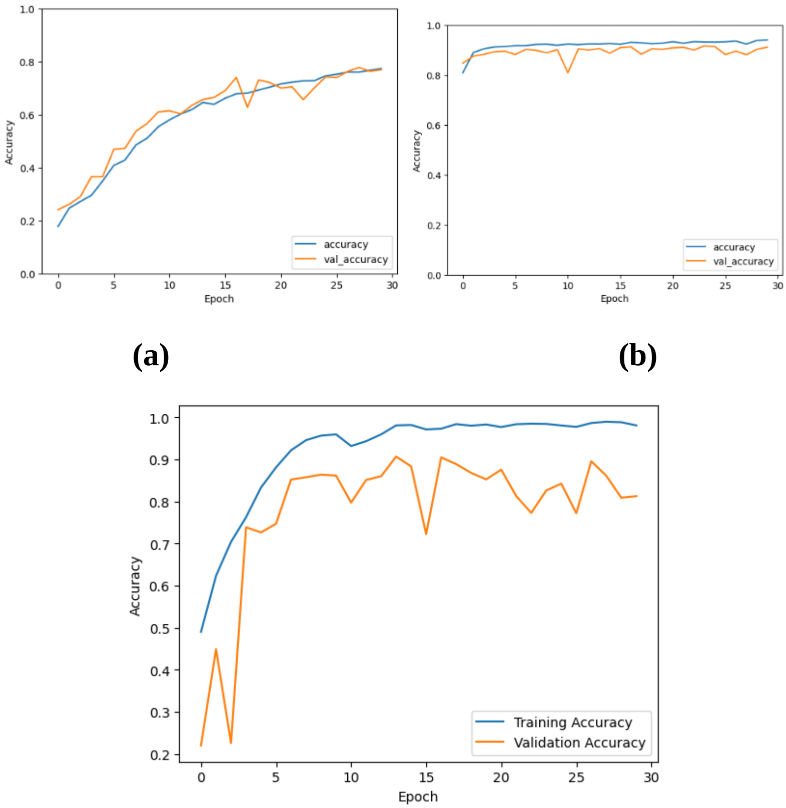


Figure 4. Model Performance Comparison



(c)

Figure 5. Train-Validation Graphics

CONCLUSION

This study systematically evaluated the performance of U-Net, FCN, and DeepLabV3+ architectures on the PlantVillage dataset, revealing U-Net's superior capacity for plant segmentation, as evidenced by its 91.18% accuracy, 91.80% F1 score, and 77.20% IoU. The incorporation of skip connections was instrumental in capturing fine-grained features, thereby enhancing segmentation performance. In addition to comparing these leading architectures, the findings demonstrated the applicability of U-Net-based systems in agricultural robotics, plant health monitoring, and precision agriculture (Fuentes et al., 2017), supported by a processing speed of 12.6 frames per second for real-time monitoring and intervention. Future research should investigate the following: model generalisation under diverse environmental conditions (Wang et al., 2017);

the employment of transfer learning to adapt to new plant species and diseases (Ferentinos, 2018); the reduction of computational overhead for mobile deployment (Howard et al., 2017); and the exploration of emerging deep learning frameworks such as Vision Transformers and the Segment Anything Model for plant segmentation (Dosovitskiy et al., 2021). This study emphasises the transformative role of AI-driven solutions in agricultural productivity and sustainability by underscoring U-Net's high accuracy, precision, and real-time processing capabilities for early disease detection and decision support.These insights contribute to the digital transformation of agricultural technologies and affirm the increasing impact of artificial intelligence in achieving sustainable agriculture and global food security goals (FAO, 2020).

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BÖLÜM 3

The Role of Robotic Process Automation in Türkiye's Industry 4.0 Transformation

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1. INTRODUCTION

The process of digitalization is leading to profound changes in the business world, enhancing efficiency across numerous industries (Ahmet Unal & Bolukbas, 2021). Robotic Process Automation (RPA) offers significant advantages, particularly in automating repetitive and time-consuming tasks. Within the framework of Industry 4.0, the application of RPA is becoming increasingly widespread across various sectors globally, accelerating business processes and reducing costs in industries ranging from manufacturing to healthcare, education, and finance.

This study examines the use and benefits of RPA in different sectors both in Türkiye and worldwide, while also discussing the potential challenges faced by RPA implementations in Türkiye and how these challenges can be overcome.

Case studies conducted worldwide reveal that RPA delivers tangible benefits, such as increased productivity, reduced error rates, and lower costs. However, applications in Türkiye face various challenges, influenced by factors such as technological infrastructure, workforce skills, and regulatory issues. This article aims to propose the necessary steps and strategies for the widespread adoption of RPA technology in Türkiye.

2. INDUSTRY 4.0 and RPA

2.1. Industry 4.0 and Its Components

Industry 4.0 represents a transformative industrial revolution aimed at digitizing and optimizing manufacturing processes through the integration of advanced technologies. This paradigm shift leverages key components such as cyber-physical systems, the Internet of Things (IoT), artificial intelligence (AI), big data analytics, cloud computing, augmented reality, simulation, and both horizontal and vertical integration (Sharma, Yadav, & Joshi, 2024; Tay, Hamid, & Ahmad, 2019). Figure 1 provides an overview of Industry 4.0's key technologies. These technologies collectively enhance the flexibility, efficiency, and customization of production systems while enabling smart manufacturing processes, including smart design, machining, monitoring, control, and scheduling (Namjoshi & Rawat, 2022).

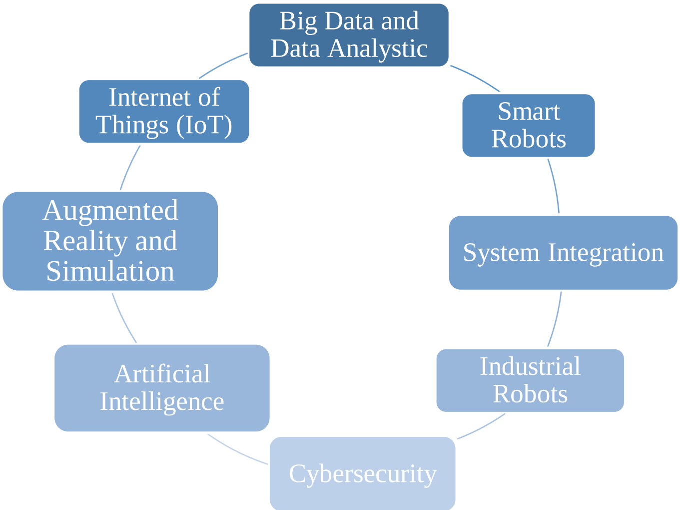

Figure 4. Core components of Industry 4.0

At the core of Industry 4.0 lies the concept of smart factories, recognized as foundational pillars that facilitate automation and autonomous operation in manufacturing (Yıldız, 2018). The implementation of these technologies offers numerous benefits, such as waste reduction, increased productivity, and improved efficiency, while also enabling highly customized production (Sharma, Yadav, & Joshi, 2024). By fostering interconnected and self-optimizing industrial environments, Industry 4.0 transforms traditional manufacturing by allowing devices to communicate autonomously across the value chain, thereby enhancing global competitiveness. However, challenges persist, particularly for small and medium-sized enterprises, which often struggle with financial and technical resource constraints (Sharma, Yadav, & Joshi, 2024). Despite these barriers, the continued adoption of Industry 4.0 technologies is reshaping the industrial landscape, paving the way for more resilient and adaptive production systems.

The impact of Industry 4.0 in Türkiye holds significant importance for boosting industrial productivity and strengthening global competitiveness. Automation and digitalization, in particular, present substantial opportunities to enhance workforce efficiency while simultaneously reducing operational costs and accelerating production rates. By fostering innovation and optimizing resource utilization, Industry 4.0 technologies position Türkiye to address evolving market demands and align with global industrial trends.

2.2. RPA Technology

RPA is a technology that automates business processes through software robots. RPA is particularly effective in performing repetitive, rule-based, and manually intensive tasks quickly and efficiently. Software robots integrate with systems via user interfaces to perform tasks such as data entry, reporting, email responses, and customer service (Arslan, 2021).

RPA offers a flexible solution that can be applied in both large enterprises and Small and Medium-sized Enterprises (SMEs). In Türkiye, the areas of application for RPA are typically concentrated in high transaction-volume sectors, such as finance, banking, and customer services. However, further research and infrastructure development are required to implement RPA in less developed sectors (İren, 2022).

2.3. Advantages and Disadvantages of RPA

The primary advantages of RPA include significant time and cost savings, minimizing errors, and enhancing productivity. RPA, particularly in repetitive tasks, provides high speed and accuracy. By freeing up human labor, it enables employees to focus on more strategic and creative tasks. Additionally, the ability of RPA to operate 24/7 ensures that business processes continue uninterrupted and efficiently. However, RPA also has several disadvantages. These include high initial costs, infrastructure requirements, and the need for staff training. Furthermore, RPA may be inadequate for handling complex tasks that require emotional intelligence, as it is limited in situations that necessitate human interaction (Arslan, 2021).

Table 1. Advantages and Disadvantages of RPA

Advantages	Disadvantages
Time and Cost Savings	High Initial Cost
Minimizing Errors	Infrastructure Shortcomings
Increased Productivity	Insufficient Staff Training
Continuous Operation	Limited Flexibility
Easy Integration	Requirement Analysis

3. APPLICATION AREAS OF RPA IN TÜRKİYE

RPA is an innovative technology that is increasingly recognized in the modern business world and plays a key role in restructuring business processes across various sectors. In today's business landscape, RPA has become a powerful tool for rapid and effective transformation (Çalışkan & Kıran, 2020). The use of RPA in Türkiye spans a broad range of sectors, with variations based on industry-specific needs. The sector-specific application of RPA in Türkiye offers numerous advantages, such as accelerating workflows, reducing operational costs, and minimizing errors, thereby enhancing the competitiveness of businesses (Özdem & Bora, 2022). The application areas of this technology are widespread, demonstrating its strength and potential across different sectors, including Banking and Finance, Insurance, Education, Auditing and Electronic Document Management Systems, Retail, Logistics, and Accounting.

3.1. Use of RPA in the Banking and Finance Sector

One of the most common areas of RPA application in Türkiye is in the banking and finance sectors, which are characterized by high transaction volumes. Banks have streamlined their operations by automating customer applications, reducing processing times, and improving customer satisfaction (Yetiz, TURAN, & CANPOLAT, 2021). Additionally, RPA has been employed in accounting and financial reporting, saving time and enhancing efficiency. The Turkish banking sector is one of the leading areas in the advanced application of RPA technology. In banking, RPA has addressed operational challenges caused by repetitive manual processes, increasing efficiency and transforming the way business is conducted. RPA improves customer experience, ensures error-free operations, and delivers cost savings. Banks use RPA to automate routine tasks such as reporting and document management (Demir, 2024).

Table 2. Areas of RPA Application in the Banking Sector in Türkiye

Application Area	**Benefit Provided**
Customer Services	Faster processing and customer responses
Data Entry and Reporting	Reduced error rates and faster reporting
Risk Assessment	More accurate and efficient analysis
Needs Analysis	Quick response to customer demands
Customer Services	Faster processing and customer responses

Case Study for Banking KYC: HDFC, one of the largest private sector banks in India, faced a surge in new customers, which resulted in a significant administrative burden. Know Your Customer (KYC) regulations involved time-consuming manual tasks, such as reading and processing documents required to verify the identity of new customers. This process was a substantial drain on both time and resources. To address this challenge, HDFC decided to implement an RPA solution to extract data from account applications, including scanned documents. The RPA software automated the entire KYC cycle, speeding up the process. As a result, processing times were significantly reduced, and costs and working hours decreased by 50%. Additionally, overall productivity increased by 60%, and human errors were substantially reduced (Datamatics, 2019).

3.2. Use of RPA in the Insurance Sector

The insurance industry is increasingly turning to RPA solutions to meet the needs of digital transformation, cost reduction, and improved efficiency. RPA automates repetitive and time-consuming tasks, improving operational efficiency, reducing error rates, and cutting costs. It is particularly widely used in processes such as policy writing, claims automation, claim processing, and underwriting.

Through the use of RPA, insurance companies are making significant improvements in manual processes while redirecting personnel resources toward more valuable tasks. Additionally, the integration of RPA with legacy software and existing systems accelerates the digital transformation process. RPA provides cost advantages and enhances customer satisfaction, thus improving the competitiveness of the insurance sector.

Case Study in the Insurance Sector: One of the first RPA case studies applied in the insurance industry focuses on the transition from labor-intensive and paper-based processes. This case study presents an example of the challenges faced by an international insurance company based in the Czech Republic. The company encountered significant difficulties due to new regulations and the inefficiencies of paper-based processes and inconsistent workflows. In this context, the organization decided to embark on a digital transformation process. By adopting an agile approach, the company restructured its insurance quote preparation processes digitally, consolidating workflows and data management on a single platform. Additionally, RPA technologies were leveraged to automate these processes. This transformation resulted in significant success for the insurance company. With the use of RPA, the quote preparation time was reduced by 40%, operational costs were lowered by 50%, and the error rate was decreased to below 1%. This case study serves as a concrete example of the effective application of process automation in the insurance sector (Marek, Blümlein, Neubauer, & Wehking, 2019).

3.3. Use of RPA in the Manufacturing Sector

In the manufacturing sector, a large portion of repetitive, rule-based tasks can be automated through RPA. RPA enhances efficiency in critical areas such as order processing, payment handling, and inventory management. Order approvals, product selection, and payment transactions are completed quickly, and vendor transactions are also automated. Furthermore, the accurate and up-to-date tracking of inventory levels, along with forecasts based on historical data, allows companies to manage their supply chains more effectively.

RPA also brings significant improvements in service processes, such as automating customer queries, tracking shipment statuses, and handling email confirmations. Human Resources (HR) are focused only on tasks that require judgment and interaction, while routine tasks are carried out quickly and accurately by software robots. As a result, manufacturing companies reduce payroll costs while increasing overall operational efficiency and accuracy.

Case Study in the Manufacturing Sector: In a study examining RPA applications across various sectors, (Radke, Dang, & Tan, 2020) discuss the challenges faced by ABC Electronics, a manufacturing company based in Vietnam. Despite offering mobile phone repair services, the company struggled with creating a material list using its Enterprise Resource Planning (ERP) system. The existing process required exception requests to be transferred to the supply chain management system (GCSM). These requests were manually downloaded by operators and transferred to Excel spreadsheets. Additionally, the purchasing team needed access to internal systems to determine material requirements, while production planners manually checked reports. This resulted in unnecessary human intervention and inefficient workflows. The most critical issue was that part and material shortages caused significant service delays in the repair process.

To address this problem, ABC Electronics decided to implement RPA in certain departments while other departments continued to use traditional methods. The results demonstrated significant benefits from RPA implementation. After adopting RPA, the time spent on processing requests decreased by 80%, productivity and job satisfaction increased, and human errors were greatly reduced. Furthermore, compliance levels improved, and data accuracy was significantly enhanced. The improvements in the process also reduced costs associated with poor production and manual labor, as well as the risks of reputation loss due to customer dissatisfaction (Radke, Dang, & Tan, 2020).

3.4. Use of RPA in the HR Sector

HR departments involve many repetitive and time-consuming tasks, such as processing employee data and maintaining records of leaves and absenteeism.

Most of these processes are handled manually, leading to time loss and an increased risk of errors. RPA allows these processes to be managed more quickly, accurately, and efficiently. The use of RPA in HR processes provides significant advantages, especially in recruitment. Traditional recruitment processes, which require numerous steps and manual tasks, can lead to coordination issues and delays between different departments. RPA automates tasks such as processing recruitment documents, introducing employee accounts into systems, and sending offer letters, speeding up the process and minimizing human error. It also facilitates interdepartmental collaboration by managing system entries and access permissions.

Case Study in the HR Sector: One of the leading steel manufacturers in the United States, experiencing continuous growth, frequently needed to hire new employees. However, the company's operations, spread across multiple locations nationwide, made the recruitment process complex and labor-intensive. This led to difficulties in coordination between operations and highlighted the need for interdepartmental collaboration. Specifically, the IT and HR departments were required to provide system access details for new hires and allocate laptops, which caused delays in the recruitment process, decreased productivity, and occasionally led to disorganized workflows.

To address these challenges and create a more efficient system, the company decided to implement RPA technology. RPA automated many steps in the recruitment process, enabling the reading, understanding, and updating of documents in the company's database. Additionally, it automated the preparation of offer letters for new hires and the creation of necessary documentation. RPA was also effectively used to manage software entries and access permissions for different roles within the company.

The adoption of RPA resulted in a significant increase in the efficiency of the company's recruitment process. The process became faster and error-free, resulting in time and cost savings. Furthermore, employee satisfaction improved, creating a more organized and effective recruitment process (AQLTech, 2020).

3.5. Use of RPA in the Telecommunications Sector

The telecommunications sector is known for handling large volumes of data and complex transaction demands. RPA optimizes repetitive, data-driven processes in this industry, enhancing efficiency, reducing operational costs, and improving accuracy. Critical processes such as SIM swaps, billing management, and order processing can be performed faster and without errors using RPA. By automating these processes, RPA enables faster service delivery, increases customer satisfaction, and minimizes error rates. Additionally, it reduces labor costs and enhances operational flexibility. Telecommunications companies can lower costs, improve service quality, and strengthen their competitive advantages with RPA.

Case Study in the Telecommunications Sector: An Australian telecommunications company launched a large-scale operation to provide broadband access under the National Broadband Network (NBN) program to meet the growing demand for internet access. However, this process was creating operational challenges for the company. To deliver fast and efficient service while maintaining high service levels, a scalable solution was required. These types of tasks were ideal for the application of RPA.

The operation was based on four key objectives:

1. Improving service cycle times
2. Providing excellent customer experiences
3. Reducing service and operational costs
4. Optimizing workforce output and productivity

To achieve these objectives, the company used 50 RPA bots to enhance efficiency in two major processes: Quality Assurance (QA) and Order Creation. With the help of RPA, more than 2 hours were saved per order, and the company's labor costs were significantly reduced. As a result, the company achieved savings of approximately $5 million in delivery operations and operational costs (Cognizant, 2021).

3.6. Use of RPA in the Education Sector

In the education sector, RPA plays a significant role in digitizing processes, particularly in large and complex institutions such as universities. As part of the concept of "smart campuses," RPA automates repetitive, time-consuming, and rule-based tasks, improving efficiency and reducing error rates.

The use of RPA technology in the education sector contributes to the more effective and efficient management of administrative tasks as part of the digital transformation process in universities (Akyol, Dogan, & Er, 2023). Educational institutions can accelerate their digitalization processes with RPA technology, providing better services to students and staff. In universities with large student populations, such automation solutions become essential for speeding up processes and enhancing the quality of service (Akyol, 2024).

Case Study in the Education Sector: The education sector, especially large and complex institutions, greatly benefits from the advantages offered by RPA. RPA automates repetitive and time-consuming administrative tasks in large educational institutions such as universities, increasing efficiency and reducing error rates (Oluçoğlu, Doğan, Akkol, & Keskin, 2023). As part of the concept of "smart campuses," RPA digitizes many administrative processes in educational institutions, including registration, student information management, processing exam results, financial tasks, and student communication. A study conducted at Izmir Bakırçay University demonstrated the use of RPA technology to automate student registration and information processes. For students enrolling in master’s and doctoral programs, periodic reminder emails and course selection processes were digitalized and automated. As a result, errors caused by manual data entry were minimized, and processing times were significantly reduced. RPA eased the university’s administrative burden and allowed staff to focus on more strategic tasks (Akyol, 2024).

3.7. Use of RPA in the Accounting and Auditing Sector

RPA is a crucial tool in the auditing sector for enhancing efficiency and reducing error rates. RPA automates repetitive tasks such as financial reporting, reconciliation, and large data analysis, allowing auditors to focus on more strategic duties. This technology speeds up audit processes, reduces costs, and increases accuracy. In the accounting sector, the adoption of RPA is improving operational efficiency and reshaping the role of accountants. In this process, accounting professionals must enhance their digital competencies and use technology effectively to maximize its benefits (Topbaş, 2023).

Auditing Sector RPA Case Study: A company, which serves clients in the real estate sector, automated its auditing processes using RPA. This application involved tasks such as processing workpapers uploaded to tax software and formatting the results according to the company’s requirements. Initially, auditors were hesitant to adopt RPA, but as the time-saving benefits and the opportunity for auditors to focus on more strategic tasks were explained, these concerns decreased. Although the RPA implementation at company did not have an immediate major impact on efficiency, it did successfully redirect auditors toward higher value-added tasks. The low adoption rate at the company was due to the voluntary nature of RPA sage, and the sustainability of the implementation was limited by software updates (Parker, Issa, Rozario, & Søgaard, 2022).

3.8. Use of RPA in Electronic Document Management Systems (EDMS)

Robotic Process Automation significantly enhances the efficiency of Electronic Document Management Systems (EDMS), making important contributions to the digital transformation process. The use of RPA in EDMS offers significant benefits in terms of speed, accuracy, and cost savings when processing and managing documents. However, the ethical, legal, and technical challenges encountered during the implementation of RPA should be carefully considered, and these processes must be managed with due diligence (Yılmaz, 2021).

Case Study in the EDMS Sector: RPA is a technology that enhances efficiency by automating repetitive, error-prone, and data-intensive tasks within Electronic Document Management Systems (EDMS). This study examines the applicability of RPA through the example of the e-BEYAS application used by Ankara University since 2013.

An analysis of business processes such as user management and system administration within e-BEYAS identified processes that could be automated using RPA. Specifically, rule-based and repetitive tasks such as user creation and new role assignments can be expedited with RPA, reducing error rates. Furthermore, the process of defining supervisors, which integrates with the Signature Authorities Module (İmza Yetkilileri Modülü, İYEM), can also be automated using RPA. By speeding up EDMS processes, RPA helps institutions reduce their workload and enables them to focus on more strategic tasks (Yılmaz, 2021).

3.9. Use of RPA in the E-commerce and Retail Sector

The e-commerce and retail sectors are rapidly transforming with digitalization and are seeking innovative solutions to enhance operational efficiency. RPA provides significant advantages in the retail sector, particularly in areas such as data processing, inventory management, customer service, and reporting. By automating manual tasks, RPA delivers speed, accuracy, and consistency, which accelerates business processes and reduces costs. In the retail sector, RPA has great potential to improve operational efficiency and reduce costs. It offers an effective solution for repetitive and manual tasks. However, for full adoption and successful implementation of this technology, strategic planning and a suitable infrastructure are necessary. In the future, RPA solutions supported by artificial intelligence and machine learning will contribute to the development of smarter and more autonomous systems in the retail sector (Çolpan, 2023).

Case Study for Invoice Automation in the Retail Sector: A large North American retailer was receiving a substantial volume of invoices daily, with this number reaching up to 700 during peak periods. The processing of these invoices involved opening emails, extracting data, and then entering the information into central data systems to ensure customer payments were received. Each invoice took approximately 5 minutes to process, which caused issues regarding the efficiency of the process and the scalability of the business. To overcome these challenges, the company automated the reading and extraction of information from emails documents using Optical Character Recognition (OCR). RPA bots processed this data and transferred it to the relevant systems, ensuring accurate information and enabling quicker payments to vendors. After the new RPA system was implemented, 93% of invoices were processed without manual intervention, accuracy increased to 95%, and approximately 20% of the accounting staff were freed up to focus on more value-added tasks (UiPath, n.d.).

3.10. Use of RPA in the Logistics Sector

In the logistics sector, RPA greatly enhances efficiency by automating repetitive and manually performed tasks. RPA reduces human errors and accelerates processes in routine tasks such as invoice entry, order management, and document processing. Particularly, software robots integrate with technologies like OCR to speed up document processing and automate data extraction. As a result, the need for manual entry is eliminated.

The use of RPA in the logistics sector accelerates the digital transformation of business processes, increases efficiency, and reduces costs. These automation technologies will ensure that logistics operations become more flexible, faster, and error-free in the future, providing a competitive advantage (Yiğit, 2024).

Case Study for Shipment Tracking and Order Verification in the Logistics Sector: LTX Solutions, an Atlanta-based supply chain management firm specializing in less-than-truckload (LTL) shipments, had to implement RPA after being acquired by Redwood Logistics in 2019 to manage the increased workload. Previously, a 12-person team handled around 3,000 deliveries per month, but with business growth, they realized that manual tracking and verification processes could no longer scale.

Adding new personnel would increase labor costs by 40%, presenting a significant challenge in the supply chain sector with already thin margins. Instead, they decided to automate these processes using RPA. Initially, they automated the shipment tracking processes, which were implemented in about a day. This quick transformation became a concrete example of the speed at which RPA can drive business transformation. Subsequently, they reduced back-office working hours, improving overall efficiency. These steps played a significant role in their acquisition by Redwood Logistics (Tungsten Automation, 2019)

3.11. Use of RPA in the Customer Service Sector

Advancements in communication tools have led to higher customer expectations in their interactions with businesses. Modern consumers demand 24/7 access and self-service options. If these expectations are not met, customer loss may occur. Customer service involves many time-consuming manual tasks, and RPA provides an effective solution by automating these processes to enhance the efficiency of representatives. Specifically, RPA is used to ensure that customer interactions are consistent and up-to-date, reduce data errors, and prevent time loss.

Case Study to Support Customer Service Representatives: Cobmax, a global sales center, realized that their manual administrative systems were no longer sufficient as their business grew. After securing a contract with one of Brazil's leading telecommunications companies, it became evident that manual processes were causing issues due to high error rates and inefficiency. To address these problems, Cobmax decided to implement RPA. RPA was used to automate the process of manually copying and pasting data from one CRM system to another. This process aimed to reduce error rates and the time taken to prepare reports. Previously, errors led to delays in completing reports. By using RPA, Cobmax was able to reduce back-office operations by 50%, and the time to produce reports decreased by 66%. As a result, productivity increased, error rates significantly decreased, and customer service representatives experienced a lighter workload (Williams, 2021).

3.12. Use of RPA in the Healthcare Sector

Modern healthcare institutions face numerous challenges, including increasing patient volumes, compliance requirements, operational costs, and often bureaucratic inefficiencies. The sector has a significant need for automation to provide faster and more cost-effective care. These advancements are critical to increasing public trust in healthcare services. Access to patient data is crucial for providing optimal care. However, this data is often stored in separate databases across doctor's offices, hospitals, and other healthcare data repositories. This fragmentation leads to inefficient data requests and numerous manual processes. RPA can automate processes like test automation, making this data more accessible and faster to retrieve. As a result, doctors can quickly access the information they need to make informed decisions.

Case Study for Accessing Patient Records: The National Health Service (NHS) of the United Kingdom provides free healthcare services to the country's 67 million citizens. However, one of the main challenges faced by NHS is the inefficiencies and unnecessary processes that come with being such a large system. NHS Dorset was searching for a solution that would allow general practitioners to easily access patient health records (Digital Health, 2021). The Dorset Care Record (DCR) is a system where patient health records are stored, but the security of this data has been a significant concern. NHS Dorset implemented RPA to create accounts that allowed 1,500 general practitioners to securely and efficiently access patient records. This process saved considerable time for practitioners and provided quick, one-click access to accurate patient histories. As a result, a major issue faced by the overloaded organization was effectively addressed through RPA solutions (Digital Health, 2021).

3.13. Use of RPA in the IT Sector

RPA is a technology that has been rapidly adopted by IT departments. The main reason for this is the high adaptability of management and employees to new technologies and their quick realization of the potential benefits that automation offers. IT departments utilize RPA across a wide range of applications, from managing websites to overseeing transitions to cloud-based systems. RPA enhances efficiency by automating IT processes and offers significant cost savings to businesses. This technology accelerates complex and time-consuming tasks, allowing employees to focus on more strategic responsibilities.

Case Study for User Management in the IT Sector: Mid Yorkshire Hospital NHS Trust places a strong emphasis on the Digital Learning and Development (L&D) processes for its employees, covering both new hires and existing staff. However, user management was a time-consuming and manual process. Each new user registration took approximately 5 minutes, meaning a team of three people spent one and a half days managing 200 users. Given that NHS Trust employs over 9,000 people, this manual process resulted in significant time loss. The IT department decided to implement an RPA solution to make this process more efficient. RPA bots automatically registered users for courses and sent the relevant emails. Additionally, any errors or duplicate entries were flagged and sent to the team for manual review. This solution reduced processing time by

72%, greatly improving efficiency. With 24/7 access, error rates decreased, and the L&D staff was able to focus on more valuable tasks (NHS Digital, 2021).

3.14. Use of RPA in the Pharmaceutical Sector

RPA is widely used in the pharmaceutical sector across various areas such as management, HR, supply chain, and document management. RPA plays a significant role in reducing Research and development (R&D) costs by automating document distribution, ensuring data security, and eliminating human errors. Particularly during clinical trials, RPA provides pharmaceutical companies with key advantages by managing documents accurately and efficiently.

Case Study for Reducing R&D Costs in the Pharmaceutical Sector: (Anagnoste, 2019) outlines the challenges faced by pharmaceutical companies as they transition to a more patient-centered business model while trying to offer medications at reasonable costs. The article also highlights the compliance burdens affecting businesses in the Life Sciences field. It examines case studies of two leading pharmaceutical companies and how they set goals to improve their services.

In particular, these companies used RPA to improve clinical research documentation and compliance processes. Clinical trials are tightly regulated, and the documentation involved must be meticulously managed. In traditional processes, documents known as Green Light Forms (GLF) were manually managed. However, RPA automated this process, leading to improved compliance, reduced support needs for document management, and simplified processes. The first company used RPA to reduce costs, enhance compliance, and improve their metrics. The second company successfully improved compliance and document request processes, developing an agile approach to meet new regulations. Both companies achieved cost savings and successfully met compliance standards in a complex environment (Anagnoste, 2019).

3.15. Use of RPA in the Legal Sector

The legal sector has greatly benefited from RPA. In the past, law firms with large-scale document printing, processing, and storage facilities faced long working hours, the risk of human errors, and security concerns associated with paper-based work. RPA has reduced these manual processes, increasing efficiency and lowering error rates. The use of RPA in tasks such as creating case documents, conducting database searches, reviewing case information, and filling out reports has accelerated the work of law firms. Additionally, data migration processes have allowed law firms to move their data to cloud environments, enabling remote work and mobile access. However, all data migration projects require careful planning.

Case Study for Data Migration in the Legal Sector: A law firm needed to transfer hundreds of real estate lot records from a Microsoft Access database to a cloud-based platform. However, the new software lacked the adaptability required to upload and validate attorney records, posing a significant challenge for the firm. The firm successfully migrated the data with 100% accuracy using RPA. The process only took half a day, and the firm saved approximately 350 working hours. This case demonstrates how RPA can effectively solve not only one-time data migration issues but also long-term business process challenges, enabling staff to focus on more strategic tasks (Cigen, 2019).

3.16. Use of RPA in Real Estate and Property Management

RPA can be used to automate various tasks in the property management sector. This industry is characterized by many back-office business processes common to every business, most of which can be accelerated using RPA technology. For example, processes such as Know Your Customer (KYC) and Anti-Money Laundering (AML) checks can be expedited. Additionally, RPA provides an effective solution for tasks such as managing debt accounts, tenant communication, and account reconciliation. Automating lender declarations is another area where RPA can be applied in the real estate sector. Real estate development and management often require frequent manual checks to keep cash inflows up to date. These checks involve comparing files with the bank and ensuring the accuracy of accounts for tenants or property owners. Although these processes are time-consuming, RPA processes this data with high accuracy and speed, thereby increasing business efficiency.

Case Study for Automating Lender Declarations: A real estate management and development company based in Chicago, IL, was struggling to obtain monthly lender declarations and credit history reports. The tasks were primarily the responsibility of a single operator and involved a highly repetitive process. However, the fact that lender declarations arrived at any time during the last week of each month made the process even more complex. This meant that the operator had to check all the banks for each lender declaration.

The company successfully automated these tasks by implementing an RPA solution. This automation process resulted in a savings of 10 hours of work per month for the director (HubSpot, 2021).

4. SECTOR-SPECIFIC COMMON BENEFITS OF RPA APPLICATIONS IN TÜRKİYE

RPA provides significant benefits across various sectors in Türkiye. These benefits include increased process speed, enhanced efficiency, and reduced error rates. Additionally, RPA reduces costs by automating manual tasks, allowing employees to focus their time on more value-added activities. RPA also makes important contributions to areas such as simplifying compliance processes, improving data security, and enhancing customer satisfaction. Thanks to RPA technology, sectors in Türkiye are able to operate faster, more accurately, and efficiently.

1. **Increased Efficiency:** RPA automates repetitive and rule-based tasks, speeding up processes and allowing employees to focus on more valuable and strategic tasks.
2. **Reduced Error Rates:** By minimizing human errors, RPA enhances the accuracy of operations. It is particularly effective in critical areas like data processing and reporting, reducing errors.
3. **Cost Savings:** Automating tasks that require manual intervention significantly reduces time and labor costs for businesses.
4. **Business Continuity:** RPA ensures 24/7 continuous operation of processes. This guarantees the continuity of operations, especially during busy periods or in emergency situations.
5. **Time and Resource Savings:** By accelerating business processes, RPA allows more tasks to be completed in less time. It also optimizes workforce resources.
6. **Ease of Compliance and Reporting:** RPA simplifies compliance with regulatory requirements and streamlines audit processes with automated reporting.
7. **High Scalability:** RPA systems are capable of handling high volumes of data and transactions, addressing the needs of growing businesses.
8. **Enhanced Data Security:** Automated systems follow specific security protocols, improving data security by reducing the risk of unauthorized access and potential security vulnerabilities.

5. COMMON CHALLENGES AND POTENTIAL RISKS FACED BY RPA APPLICATIONS IN TÜRKİYE'S SECTORS

Businesses in Türkiye face several key challenges when implementing RPA applications, including the lack of sufficient workforce training to keep up with digitalization, insufficient investment in technology, and inadequate infrastructure. Small and medium-sized enterprises (SMEs), in particular, face difficulties transitioning to RPA due to high costs and technical challenges. Another significant challenge is the difficulty of integrating RPA with existing legacy systems. Additionally, the impact of automation on the workforce, particularly for employees in manual jobs, raises concerns.

1. **High Initial Costs**: Implementing RPA systems requires software and hardware investments, which can be a significant financial burden, especially for SMEs.
2. **Technological Compatibility and Integration Issues**: During RPA integration with existing systems, incompatibilities may arise, complicating the transition process and potentially disrupting workflows.
3. **Data Security and Privacy Risks**: RPA applications, particularly in sectors handling sensitive data, can pose data security threats. Moreover, these systems may be more vulnerable to external cyberattacks.
4. **Employee Adaptation**: Transitioning to new technologies requires employees to adapt. The training and adaptation process can take time, which may initially affect productivity.
5. **Technical Failures and System Errors**: RPA systems can experience software bugs or technical glitches, which may disrupt critical processes and require manual intervention.
6. **Lack of Flexibility**: RPA systems work with specific rules and structured processes, making them inadequate for situations that require flexible solutions. Complex or unique cases may still require human intervention.
7. **Dependency and Business Continuity Risk**: Over-reliance on automation systems can lead to significant disruptions in business processes in the event of a system failure, potentially threatening business continuity.

8. **Reduction of Human Input**: Excessive automation may prevent employees from utilizing their skills, leading to a reduction in human interaction in areas like customer service.

9. TÜRKİYE'S STRATEGIES AND FUTURE PERSPECTIVE ON INDUSTRY 4.0 AND RPA

9.1. Education and Workforce Development

In Türkiye's Industry 4.0 transformation process, workforce training is a critical factor for adapting to digitalization. Specifically, qualified personnel are needed for the maintenance and management of software robots and automation systems. To promote the widespread adoption of RPA in Türkiye, strong collaboration between universities and industry should be established, and educational programs that provide digital skills should be expanded.

9.2. Digitalization for Global Competitiveness

Türkiye's rapid adaptation to Industry 4.0 will enhance its global competitiveness. RPA and other digital solutions will increase the efficiency of Turkish companies, making them more competitive in the global market. For RPA to be effectively utilized, investments in digital infrastructure should be increased, workforce competencies should be developed, and industry-specific digital solutions should be pursued.

10. CONCLUSION AND RECOMMENDATIONS

RPA plays a critical role in Türkiye’s Industry 4.0 transformation. This technology presents a significant opportunity to enhance Türkiye’s global competitiveness. However, effective utilization of RPA requires investments in infrastructure, workforce training, and industry-specific adaptation. To accelerate Türkiye’s adaptation to Industry 4.0, investments should be made in digital education programs, and industry-specific solutions should be developed.

RPA has great potential to speed up business processes and increase productivity across many sectors both globally and in Türkiye. Global case studies demonstrate how effective RPA is, particularly in automating repetitive tasks. By adopting this technology, Türkiye could enhance its competitiveness by automating business processes.

However, RPA applications in Türkiye may face certain challenges. Barriers such as insufficient technological infrastructure, gaps in workforce skills, and regulations may hinder the widespread adoption of this technology. To overcome these obstacles, the focus should be on developing the right strategies, investing in education, and improving digital infrastructure. Successfully adopting RPA applications will, in the long run, help businesses reduce costs, increase productivity, and allow them to focus on more strategic tasks.

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BÖLÜM 4

Smart City Components With Internet of Things and Machine- To- Machine Communications Technology: A Survey

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The concept of a smart city is considered a new model for urbanization and economic, social, and technological growth. Although the concept dates back to the 1990s, there is still no unified theoretical framework for smart cities.The only common point between existing concepts is the use of information and communication technology. Information and communication technology is considered as a key factor in supporting services that provided to citizens as the main component of a city (Wenge, Zhang, Dave, Chao, & Hao, 2014)

The modern world comprises numerous physical objects, infrastructures, and devices interconnected through sensor networks and intelligent agents. This interconnectivity allows them to perform functions such as environmental monitoring, status reporting, receiving commands, and responding based on the gathered information. This concept is now known as the Internet of Things (IoT)(Bradley, Barbier, & Handler, 2013). According to Gartner's research firm, IOT is a network of physical objects that includes a set of embedded technologies for communicating, sensing and interacting with the external environment or the internal components of an object (Gartner, 2016) Also, according to the more complete definition provided by ITU and IERC, IOT is an infrastructure for launching a global dynamic network with self-configuration capabilities that is based on standard communications protocols and compatible with other parts of the network.Within this infrastructure, both physical and virtual objects possess unique identities, physical attributes, and digital personas, seamlessly integrated into the information network through intelligent interfaces (Shancang, Xu, & Zhao, 2014).

IOT is a new communications platform that is rapidly developing solutions for the wireless telecommunications scenario. Moreover, exchange of information within the chain network will optimize global resource utilization, enhance transparency, and improve efficiency.. Extensively, IOT can be used as the main framework of the inclusive system and enables the smart environments for easy identification of objects and retrieving information from the Internet at any time and place (Miorandi, Sicari, Pellegrini, & Chlamtac, 2012).

The concept of expanding the scope of wireless network-connected elements without human intervention dates back to a decade ago. Initially, numerous new devices were introduced to provide various services to users autonomously.In this regard, the promotion of safety, the optimization of various types of mechanisms, the possibility of tracing human and vehicles more efficiently will be provided (Boswarthick, Elloumi, & Hersent, 2012). Machine-to-machine communication refers to data exchange between computers, embedded processors, and mobile devices, with minimal or no human intervention (Min Chen , Jiafu Wan , Fang

Li, 2012). This study presents key applications and indicators of IoT and machine-to-machine communication within smart city environments

Tiryaki and Önder (2022) conducted a survey on the use of smart wearable objects with Internet of Things technology using the Extended Technology Acceptance Model (ETAM) by reaching 470 consumers over the age of 18 in Ankara using convenience sampling. They analyzed the model they predicted with the data they obtained using structural equation modeling and determined that technological knowledge, perceivedDespite the increasing ease of use, and perceived benefit had a significant effect on attitudes towards use, and attitudes had a significant effect on intention to use.

Bayanati (2023), in his study to investigate the use of the Internet of Things in the business world and business models; presents a framework for easier development of business models in e-commerce with Internet of Things and Blockchain applications. It is stated that the framework presented in this study, which examines mobile phone operators, can be used as a starting point to create a business model for IoT and Blockchain applications in developing countries. It is also explained that blockchain technology can help mobile phone operators solve their current business problems, which will provide great savings in operating costs and financial losses

Qadir et al. (2023) explain the latest activities and trends in 6G technology, network requirements and enabling technologies required for 6G networks in their studies. They emphasize that 6G networks should be designed to effectively meet the demands of the new communication systems era in cases where 5G communication systems are not sufficient. They also investigate emerging 6G connectivity solutions such as holographic beamforming, AI-enabled IoT networks, edge computing and backscatter communications to serve shopping malls. In addition, they emphasize the need to develop 6G systems and enabling technologies for their applications in the Internet of Things in the face of the increasing digital divide globally.

1. Smart City and Its Goals

Work on the concept of smart city is still underway. Throughout the world, the concept of smart city is done with different names. A wide range of concepts has been produced in this regard. Some are recognizing the use of smart cities as a metropolitan phenomenon (Boulton, Brunn, & Devriendt, 2011)

Here are some definitions compatible with both scientific and practical use. A smart city is characterized by a well-integrated combination of citizen activities, economic development, governance, mobility, and environmental sustainability (Giffinger, Fertner, Kramar, & Kalasek, 2007). A smart city is characterized by its ability to monitor and integrate various critical infrastructures, such as roads, tunnels, bridges, railways, subways, airports, ports, communication networks, water supply, electricity, and large buildings, while ensuring optimal services for its citizens (Hall, 2008).The term "smart city" is often associated with its overarching objectives, where greater intelligence is linked to increased efficiency, stability, and fairness (Alawadhi, Aldama-Nalda, Chourabi, & Leung, 2012) Fundamentally, the concept revolves around viewing the city as a system composed of multiple interconnected infrastructures (Ghourabi, Taewoo, Shawn, & Ramon, 2012).These subsystems function collectively, enabling the city to operate in a coordinated and intelligent manner (Colldahi, Frey, & Kelemen, 2013). Since urban environments consist of diverse and often unpredictable interrelations, smart city models aim to develop effective strategies to navigate these complexities and enhance the quality of life for urban dwellers (Nam, T., Pardo, T.A., 2011).

The main objective of a smart city is to deliver intelligent services across all essential urban functions. Analyzing smart city initiatives worldwide reveals key goals such as reducing carbon emissions, enhancing energy efficiency, leveraging information and communication technology for industrial development, improving the quality of life for residents, expanding urban green spaces, and advancing information infrastructure.

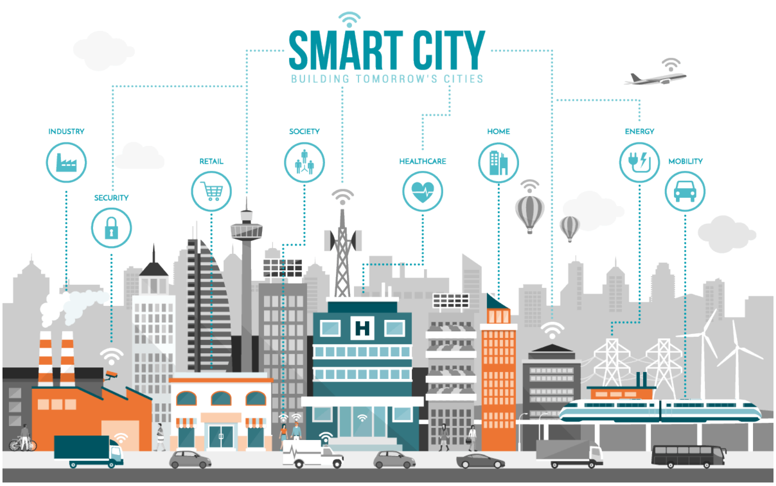

Fig 1: Smart city

2. Smart City Components

A smart city is viewed as a large-scale system composed of various elements, including subsystems. These subsystems and subcategories operate with distinct and independent objectives, carrying out their designated roles and responsibilities within their respective domains. To achieve the overarching goal of a smart city, these components must function in a well-coordinated and interconnected manner, ensuring seamless integration and interaction These components include: Urban Smart Intelligence, Intelligent Energy, Intelligent Building, Intelligent Transportation, Intelligent Infrastructure, Intelligent Technology, Intelligent Health Care, Intelligent Citizen(Chui, Loffler, & Robert, 2010) "Fig.2" shows the conceptual model of the smart city.

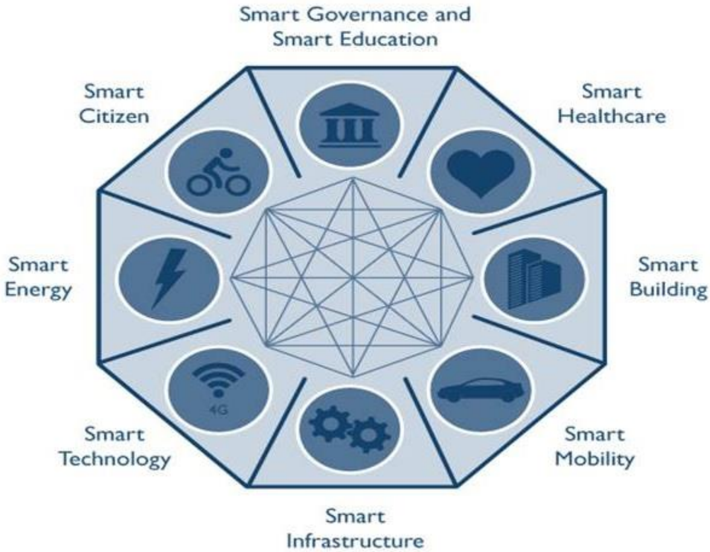

Fig2: Conceptual Model Of The Smart City

3. Internet of Thing

The concept of IoT was first introduced by Kevin Ashton, and its practical implementation became a reality a decade later (Ashton, 2009). IoT has progressively evolved into a fundamental component of the Fourth Industrial Revolution, serving as a key enabler of digital transformation. This technological shift significantly influences the development of IoT-based smart city applications. Furthermore, IoT is often regarded as the third wave of technological evolution, following the advent of computer technology, the Internet, and mobile telecommunications (Santucci, 2019)

IOT to create a smart world is a universal concept that can be applied to all areas of energy, transport, health, etc. The technology provides the provision of advanced services through the physical and virtual connection of objects and the use of available technology and the advancement of information and communication technology. This technology enables the identification and processing of data, allowing for the provision of diverse services through multiple applications.. From the technology presented in IOTcan be referred to machine-to-machine communications, automatic networks, data mining and decision making and security and privacy protection "(Dr. V. Bhuvaneswari, Dr. R Porkodi 2014).

4. Internet of Thing (IoT) Generic Architecture

The architecture of Internet of objects is divided into four layers as you can see in the "fig.3".

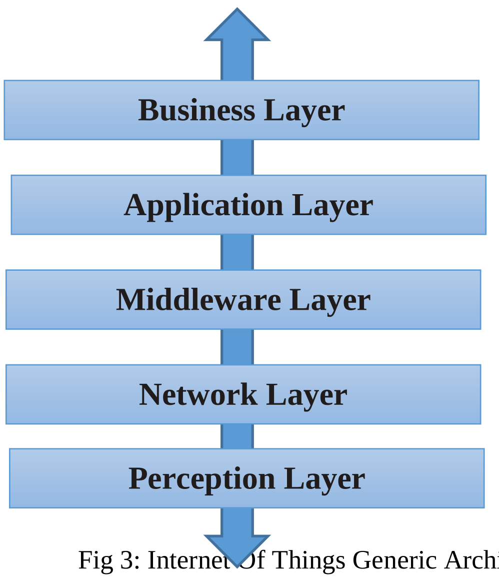

Fig 3: Internet Of Things Generic Architecture

Perception Layer: This layer, which contains different types of sensors and environmental elements, resembles the physical layer in OSI model. In general, this layer deals with the management of devices, identifying and collecting information collected by sensors. This gathered information can include location, wind speed, vibration, humidity, airborne dust levels.

Network Layer: This layer plays a crucial role in securely transmitting and relaying sensitive data from sensors to the central information processing system using technologies such as UMTS, Wi-Fi, WiMAX, RFID, Infrared, and Satellite. Its primary function is to transfer information from the perception layer to higher layers in the system.

Middleware Layer: The devices available on IOT when connecting and communicating with each other produce different types of services. This layer contains two basic functions, service management, and store low layer information.

Application Layer: This layer is responsible for overseeing applications that utilize data processed in the middleware layer. Internet of Things applications in this layer include smart postal services, smart healthcare, smart vehicles, smart wearables, smart homes, independent living solutions, and intelligent transportation systems.

Business Layer: This layer encompasses all IoT applications and service management functions. It facilitates the creation of practical outputs such as graphs, business models, flowcharts, and executive reports. The operations within this layer rely on the data received from lower layers and efficient data analysis processes (Kraijak & Tuwanut, 2015).

5. Machine-To-Machine Communication

One of the key technologies contributing significantly to IOT is machine-to-machine communication. In fact, IOT has made remarkable progress with the help of machine-to-machine communication, and much of its coverage is due to the advancement of this technology. Machine-to-machine communication is a combination of heterogeneous electronic equipment, software technology and communication. This network is designed to reduce or eliminate human intervention. Machine-to-machine communication is generally a combination of three wireless sensor technologies, the internet and personal computers. This technology supports wireless communication between the machine to machine. The main function of machine -to-machine communication is to create conditions for the exchange of information between a device and a business application in bilaterally on network-based communications. This kind of communication involves a node or group of nodes associated with the application. In some cases, equipment is not directly related to the application. In these cases, the communication is established by the intermediate equipment. The application or agent translates the received data into understandable data. Machine to machine Networks are capable of controlling billions of processes, equipment and machines (Tekbiyik & Uysal-Biyikoglu, 2011). The structure of the machine-to-machine communication is shown in “fig.4”.

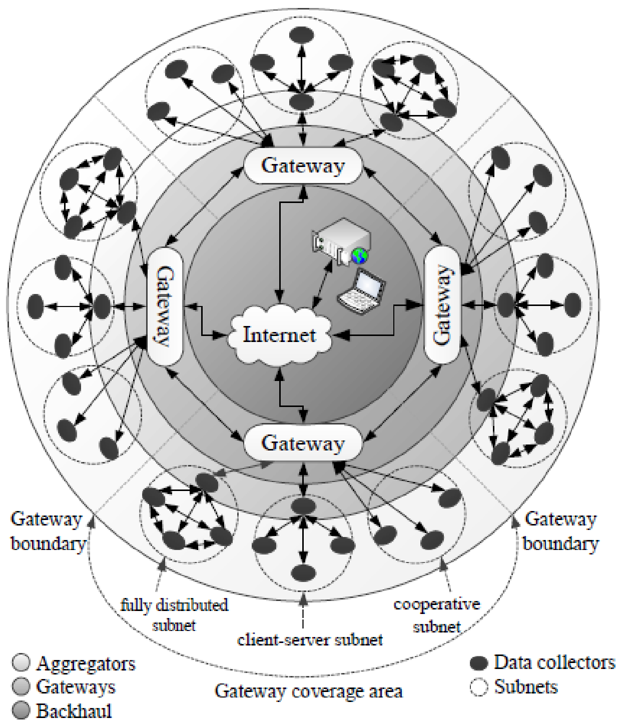

Fig 4: Machine To Machine Communication [22]

6.An Important Internet of Things Application in Smart Cities

In this section, we will review some of the most important IOT components on the basis of machine-to-machine communication.

6.1. Smart Energy

Public awareness of the evolving trends in energy supply, consumption, and infrastructure is growing. Due to various factors, future energy sources should move away from reliance on fossil fuels. An alternative to the future is nuclear energy. As a result, energy supplies for the future are largely renewable sources. It must be focus on the behavior of energy consumers who are increasing day by day. Due to the nature of the demands, it is necessary to provide a smart and flexible power grid that can respond to power fluctuations with proper configuration. Such a function based on smart grid devices and network infrastructure elements that will largely be built on the concepts of the Internet of Things. Although this ideal requires insight and information about the energy consumption of devices, supplies and industrial equipment and collecting energy usage information at the customer level is the first appropriate approach (Perera, Zaslavsky, Christen, & Georgakopoulos, 2014).

Future energy networks will be defined by a high number of small to medium-sized distributed resources, along with power plants that can be integrated with virtual power plants. In the event of a power failure or natural disaster in a particular area, required energy may be supplied from derived network with internal energy sources. Such as a photovoltaic system on roofs, a block of heat and energy storage for a residential area. Extensive competition has been made to enable technologies such as physical cybernetic systems that design energy infrastructures and unable to generate static electricity and flexible enough to supply heterogeneous energy or exit from the network and it's impenetrable against accidental and deliberate manipulation. Physical cyber integration of engineering systems and existing power grid technology and other facility systems is a major challenge (Perera et al., 2014). Increasing the complexity of the system is a technical challenge that to be considered. Security is a critical concern for system vulnerability and stakeholder information protection. This challenge needs to be addressed with the application of IOTwhich integrates heterogeneous cybernetic systems" (Roman, Najera, & Lopez, 2011).

7.2. Smart Building

Buildings equipped with Internet of Things provides significant opportunities for minimizing costs through energy optimization. The primary function of home networks is media distribution. However, they can also incorporate intelligent network components.. Media distribution systems consist of : storage media (server), media transport (wifi and bluetooth,etc.), media consumption (smartphone, computer, etc). The home network is made up of smaller home networking equipment. Each network can include a collector that connects to the Internet gateway (router). Examples of these sub-networks include: ZigBee subsystems (electrical appliances, air-conditioners), WiFi sub-networks (laptops, printers, media servers), HDTV subnets (Video camera), Smart subnet (smart measure, intelligent thermostat, smart switch), Sub-networks of the body (smart phone, body sensor) and sub-networks of Bluetooth (music center, portable audio players). These networks include devices that can connect to the Internet, offering additional services to consumers.. For example, consider a fridge for a home. This fridge can be part of a machine-to-machine network. The fact that the fridge is able to collect information about the number and status of the items available. For example, the number of eggs remains and the amount of milk contained in a container. In the context of the Internet, and through relevant home routers, it can report the number of goods and refrigerator status to the food chain and finally carry out a food recycling chain in all homes where the monitoring is being carried out (Dutton, Creese, & De Roure, 2014).

Smart home can also play an important role in improving the lives of elderly and disabled people and in their rescue operations after a heart attack or sudden fall. For this reason, it is very efficient to use a care system in the homes of people with disabilities, with the ability to set up and install which can manage personal activity. One of the most important applications of intelligent building systems is the remote health monitoring of particular patients or the elderly (Baldini, 2015).

By creating an ecosystem of technology companies, start-ups and research institutions smart cities can attract investment and talent and create new business opportunities.

Fig 5: Smart Bulding in the Smart City

7.3. Smart Transportation

In the near future, all vehicles will automatically operate and will be able to coordinate themselves with the intelligent transportation system, roads, lights, guidance boards, online driving and parking. Transportation applications not only refer to automated and connected vehicles, but also the ability to develop intelligent transport infrastructure on roads, airports and parking lots. Part of these perspectives is being implemented at Newcastle, so that a test system sends drivers a signal to match their speed when changing the color of the traffic light. Also in Milton Keynes, there are sensors for parked unmanned cars that are being tested (TIA Board Member, 2015). The London City Airport has been using IOT application to improve its customer service. To this end, a set of sensors has been put across the airport to connect to the control center for collecting and transmitting data. Travelers can connect to this system using their mobile phone and receive information such as waiting time at the airport and their route to board the aircraft. Airport employees will be able to control the conditions and improve the delivery of services to passengers by using this system (Jame, 2014). But along with the benefits of using this system, there are a lot of challenges in the field of this technology in the transportation system. The most important challenges are reliability and unexpected events such as managing unpredictable interactions with pedestrians or road construction or falling mountains (Dutton et al., 2014).

The importance of advanced robotic vehicles collaborating with intelligent systems is expected to increase significantly. In particular, autonomous vehicles and drones are anticipated to leverage artificial intelligence and autonomous decision-making software to navigate environments, with hardware advancements playing a crucial role.These systems make real-time decisions packets using advanced algorithms and sensor data to retrieve delivered safely and efficiently. For example, artificial intelligence algorithms can analyze the instant traffic situation and optimize efficiency to dynamically change delivery routes. But this lidar, radar and data from different interfaces, such as cameras happens.

Integration of sensor technologies plays an important role in the delivery process play a role. For example, lidar sensors provide a three-dimensional map of the vehicle's surroundings.Precise navigation and obstacle avoidance. Radar and cameras,tools by contributing to the perception of objects and environmental awareness.

Diverse and dynamic, such as busy city streets and unpredictable weather conditionsoperate autonomously in environments These systems coupled with fleet management software, the final stage is dynamic for deliveryrouting, reducing transportation costs and delivery costs.Allows for a reduction in their duration. *(Fact.MR, 2024).*

Fig 6: Smart Transportation in Smart City[27]

7.4. Smart Health and Healthcare

With the fast-paced advancements in information and communication technology, reducing costs and increasing access to sensors, it is possible to implement e-health scenarios, including remote patient health monitoring and remote therapy. Current mobile technologies play a key role in the future of healthcare. Therefore, IOT is expected in the near future to increase the quality of care and the level of health and reduce significant health costs around the World. Also, IOTis able to change the direction of health care from treatment to prevention and give people a better idea of their health status" (Dutton et al., 2014). The potential of IOT for the provision of health care services is very high and the use of this technology can dramatically reduce costs. In general, the application of this technology in the field of health is consist of prevention and early detection of diseases and the provision of health services such as the immediate access of patients and doctors to health data. IOT can be used to continuously monitor the vital signs of patients, such as breathing, temperature, and heart rate for early diagnosis of the disease. By using connected devices, doctors can fully monitor the patient's condition (TIA Board Member, 2015).They can also be increasingly used to help patients with chronic illness by providing remote communication with specialist doctors and needless to go to the doctor's office will lead to lower costs (Dutton et al., 2014) Data collected through wearable devices includes a wide range of diet information, exercises, exposures to environmental factors such as allergies, air pollution and sun exposure, and the level of social interactions. These data cause that the medical services providers have a deeper understanding of the lifestyle of the individual and his or her of the disease history (Dutton et al., 2014). Due to the fact that medical devices are linked to human life and death, they must be of high reliability. Despite the remarkable benefits mentioned, at the moment, the launch of Internet of things system faces risks such as ill-diagnosis of illness and low reliability (McGehee, 2016)

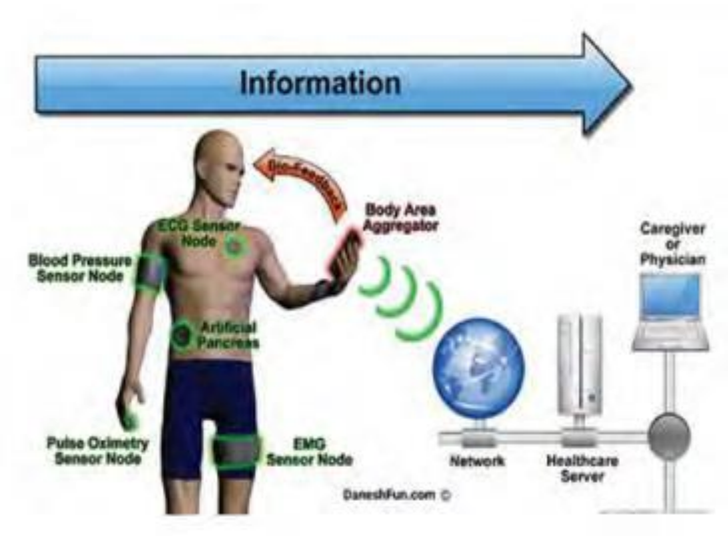

Fig7: Smart Health and Healthcare in smart city

7.5. Smart Factory

Monitoring the production line and automation is one of the most comprehensive applications Internet of Things (McGehee, 2016).The system of fire and gas leakage, lock and unlock the door automatically, cameras and tracking devices installed in factories, warehouses and equipment installed are examples of the use of the Internet of Things, which can enhance the level of security and quality of the factory performance. Also, the prediction of equipment failure, early fault diagnosis, minimizing equipment disruption and management of preventive maintenance programs is another advantage of using IOT in the factory production line (Pokric, Krco, & Pokric, 2014). Manufacturers can also track their shipments by road, rail, sea, and air transport using the interface technology between sensors and satellites. This monitoring of the source to the destination of goods reduces the probability of losing or stealing goods. Also, using on-site embedded sensors, fragile goods can be kept in good condition so that they can be properly moved during the trip. In fact, by tracking assets and using the Internet of Things, manufacturers will be able to reduce damage and defects throughout the supply chain from raw material production to final products and by reducing losses, production costs also decreases"(R.Jame , 2014).".Products such as generators, elevators, air conditioners and medical equipment that have after-sales maintenance and repair services require continuous inspection, which causes problems for the manufacturers of the equipment. Using the Internet of Things, manufacturers can remotely monitor the state of the equipment and identify imminent impairment. In this way, there is no need for a permanent repairer to be sent for a periodic visit, which leads to a reduction in costs. Also, this method which will cause the device don't have any interrupt will have benefit to the customer and ultimately, increase customer satisfaction (McGehee, 2016).

8. Data Characteristics in Smart City

Smart city devices produce data continuously. These data are significant volumes. In addition, the data rates differ from one device to another. Handling data processing at varying speeds presents a challenge. For instance, GPS sensors update their data in seconds, whereas temperature sensors refresh their readings over the course of hours. That is, the data rate produced is up and down. In addition, merging sensed data from heterogeneous sources is also a major challenge. Other characteristics of this data are their dynamism. The data of a moving car varies according to time and place.

The accuracy of data gathered from each source is influenced by three key factors:

• Errors in measurement or inaccuracies in data collection

•Environmental noise affecting devices

• Discrete observations and measurement variations

For higher quality information, a higher level of abstraction must be extracted. The quality of smart city data depends on the application and data properties and there are several ways to improve it. By increasing the frequency and sampling density, improves the accuracy of observation and measurement. Smart city and Internet of Things 's data specification are shown in" Fig.8 . Table 1 provides an overview of data characteristics in smart cities, categorizing information types and their corresponding processing locations. (Mahdavinejad et al., 2017).

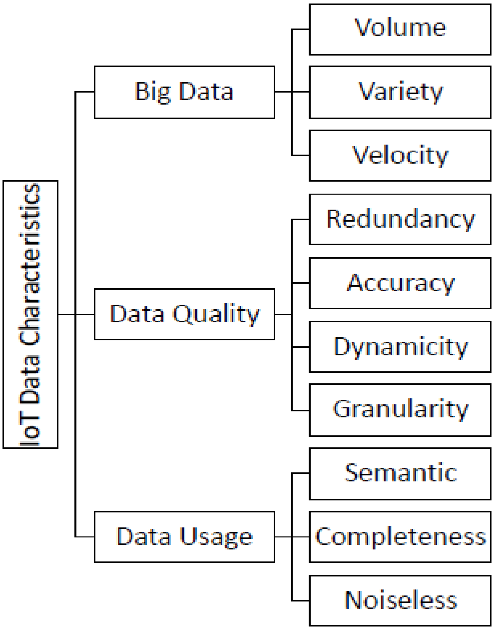

Fig 8: Internet of Things Data Characteristic

Table 1: Characteristic of Smart Data in smart cities (Mahdavinejad et al., 2017).

Smart City Use Cases	Type of Data	Where Data Processed
Smart Traffic	Stream/Massive Data	Edge
Smart Health	Stream/Massive Data	Edge/Cloud
Smart Environment	Stream/Massive Data	Cloud
Smart Weather Prediction	Stream Data	Edge
Smart Citizen	Stream Data	Cloud
Smart Agriculture	Stream Data	Edge/Cloud
Smart Home	Massive/Historical Data	Cloud
Smart Air Controlling	Massive/Historical Data	Cloud
Smart Public Place Monitoring	Historical Data	Cloud
Smart Human Activity Control	Stream/Historical Data	Edge/Cloud

Machine learning algorithms play a crucial role in various IoT-based smart city applications, optimizing different metrics for efficiency and accuracy. In smart traffic management, classification and clustering algorithms are employed to predict traffic patterns and enhance data compression Anomaly detection methods (Mahdavinejad et al., 2017). are applied in both smart traffic and smart environment systems to identify irregularities in power datasets and improve predictive capabilities (Miorandi et al., 2012). Support Vector Regression is used in smart weather prediction to enhance forecasting accuracy, while linear regression aids in market analysis, energy consumption predictions, and economic assessments by reducing data volume (Perera et al., 2014). Classification and Regression Trees (CART) contribute to understanding passenger travel patterns in smart citizen applications (Nam & Pardo, 2011).

Additionally, Support Vector Machines (SVM) are applicable across all IoT use cases, enabling real-time data classification and predictions (Shancang et al., 2014). K-Nearest Neighbors (KNN) is utilized in smart citizen applications to analyze passenger travel behavior and improve learned metric efficiency (Colldahi, Frey, & Kelemen, 2013). Naïve Bayes algorithms are applied in smart agriculture and smart citizen services to ensure food safety and estimate the number of network nodes (Giffinger et al., 2007).

K-Means clustering is widely used in smart cities, smart homes, and air traffic control for outlier detection, fraud detection, energy forecasting, and real-time data stream analysis (Ojo, Curry, Janowski, & Dzhusupova, 2015). Density-based clustering methods help label data and detect fraudulent activities in smart citizen applications (Boswarthick et al., 2012). In smart health systems, feedforward neural networks reduce energy consumption, forecast equipment states, and filter redundant information (Dutton et al., 2014). Principal Component Analysis (PCA) and Canonical Correlation Analysis (CCA) are used for fault detection in public place monitoring (Gartner, 2016). Finally, One-Class Support Vector Machines (OC-SVM) assist in smart human activity control by detecting fraud and emerging anomalies in collected data (Roman et al., 2011).

9. Security Internet of Things

Attracting public acceptance is central in the development and implementation the Internet of Things. Concerns about this are generally in the area of privacy and information security as well as new topics such as terrorism. Since cyberattacking and theft of data will have very devastating consequences for public opinion, security considerations and data governance need to be considered from the beginning and throughout cycle

Koohang et al. (2022) suggest that user awareness, privacy concerns, and security knowledge significantly impact IoT adoption. Therefore, addressing these issues in smart city implementations is crucial to ensuring widespread acceptance and secure infrastructure. Their study further highlights that increased awareness directly enhances users' knowledge of IoT privacy and security, ultimately fostering trust and reinforcing their intention to use IoT technologies.

Building on these findings, Koohang et al. (2022) propose a research model that comprises five key constructs: awareness of the Internet of Things, users' privacy knowledge of the Internet of Things, users' security knowledge of the Internet of Things, users' trust in the Internet of Things, and the continuation of the intention to use the Internet of Things.

To test their model, they conducted a study with 297 participants from various organizations across nine regions in the United States. The relationships between these constructs were analyzed using path modeling techniques. The results indicate that increased awareness of the Internet of Things positively influences users' knowledge regarding IoT privacy and security. Furthermore, this knowledge significantly enhances users' trust in IoT applications, ultimately leading to a stronger intention to continue using IoT technologies.

Additionally, the study found that IoT privacy knowledge, IoT security knowledge, and trust in IoT act as mediating variables within the proposed model. This suggests that while awareness is a crucial starting point, the establishment of trust is essential for sustained IoT adoption. These findings highlight the interconnected nature of user perceptions in technology acceptance and the need for security-focused education and awareness campaigns to promote responsible IoT use in smart city environments.

The Internet of Things. To this end, the Center Protection National Infrastructure(CPNI), the Communications and Electronic Security Group (CESG), should agree with industry and international partners on the issue of the best principles of security and privacy (Dutton et al., 2014). Security is one of the key elements in the development and deployment of the Internet of Things, which is critical to gaining end user confidence. At the same time, considerations and requirements of confidence building are more evident with the increase in the level of data and information (in each dimension of personal and non-personal) that is diverted through different methods. Although the industry is always struggling to reduce risks, it's always possible to violate the security or integrity of devices and personal information. To help reduce such risks, the industry needs to be more focused on safety and security. To overcome these dangers, the government and the industry need to cooperate together. It should be kept in mind that there is a need for coordination and coherence between different designs to avoid creating different and confusing operating rules. To this end, the government should encourage companies when designing architectures determine the appropriate security requirements for specific applications and to provide solutions based on consistent standards based on globally agreed understandings (Europe’s Newsroom, 2012).

10. Challenges in the Internet of Things

IOT encounters various challenges. In terms of scalability, IoT applications demand a vast number of devices, which can be challenging to implement due to limitations in time, memory, and processing power. For instance, monitoring daily temperature fluctuations across an entire country necessitates numerous devices and extensive data management. Additionally, the expanded distribution of the network and the resulting increase in system entry points present another challenge. Devices designed for Internet connectivity typically have a simpler structure and architecture compared to computers, making it more difficult to integrate security mechanisms. IOT is more closely integrated into everyday life than the traditional Internet, meaning that accessing such a network directly impacts users' daily activities The concept of privacy is always used with security.

In the Internet of Things, more private information than the current situation is placed on the network. One of these is the private information of a person's lifestyle. That's when we're at home, what kind of food we eat, what kind of movie we watch. Today, only 10% of the Internet traffic is encrypted, but with the growth of the Internet of Things, it is necessary to increase this figure. Increased demand for equipment with ability to network connectivity, will increase competition in this area. According to Gartner's research institute, if this prediction of joining 26 billion Internet devices by 2020 is correct, will be required more bandwidth than current bandwidth (Bagheri, 2018).

11. New Ideas of Using the Internet of Things to Build Smart City

The importance of IOT is not just in the control of home-style equipment, such as turning on or off the cooler or the refrigerator and etc., but it's important when it enters the industry, world trade and transportation and railways, and all of which has a great impact on building a city or smart city. Here, IOT is no longer a luxury or unnecessary technology and we have to prepare ourselves to encounter it from now to take place in the field of information and communication technology, industry and economics. The new applications that researchers currently work on IOT include: water resource management; manage office space such as a hospital, a library, schools, and so on; intelligent home robot; intelligent agriculture automation; smart conference halls and meetings; smart parking; smart measure energy consumption; smart protection and security system; smart refinery; Smart cars; Smart livestock; Smart Learning; Smart Banking; Smart Advertising and Marketing; etc.

One of the effects of the concentration of the population in cities has been an increase in the traffic load in the city. Urban managers develop different approaches and methods to reduce the impacts of traffic on people and the environment. However, these methods are often not sufficient to achieve the desired results. Urban logistics activities also reduce urban traffic.

As it increases, it becomes a necessity to find different solutions. Especially autonomous and artificial intelligence-assisted methods of last-stage delivery different technological solutions will be realized in the future.

The focus of these solutions will be to reduce the traffic load and transportation reducing emissions. Hyperloop delivery systems, city

The use of package transportation of rail systems inside, underground delivery pipe technologies, such as systems, will be the last alternative modes of transportation in the future. are methods that can be used in stage deliveries. The main purpose of these methods the final stage is to withdraw delivery vehicles from urban traffic, reducing both traffic and to contribute to the reduction of emissions. In addition to these technologies self-destructing packaging equipment, self-charging delivery such as robots, robotic delivery assistants and smart glasses for driverstechnologies help reduce the environmental impact of last stage delivery and improve deliveries technologies to make it even easier.

The increasing number of vehicles in cities will increase the speed of land deliveries in the future further slow down to prevent this(Alessandrini, Campagna, Delle Site, Filippi, & Persia, 2015).

Although airborne delivery systems seem to be an alternative is not yet sufficiently feasible. To increase the speed on land

One of the systems that can be used as an alternative is the underground hyperloop pipe.pipelines. These pipelines are used especially in cities with high traffic and large will be available for overland transportation between cities. First The Boring Company, founded by Elon Musk for this idea thanks to the many companies that embraced the idea right after the company.

Different initiatives have been launched on the subject. Hyperloop One, HyperloopTT and Hardt Hyperloop have built and will build underground for the development of this system for the transportation of both passengers and freight through tunnels continues its work.

The main purpose of the emergence of Hyperloop technology is to reduce traffic in cities to offer a different solution to reduce the burden

12. Conclusion

Urban developments in the contemporary world and the emergence of various challenges in the social, economic and environmental dimensions of major cities have given more attention to the reform of urban planning and management processes in the recent decade. Developing a smart city necessitates coordinated actions across multiple levels. As a broad concept, a smart city seeks to address modern challenges while leveraging the opportunities created by advancements in information and communication technology, as well as urban development.These technologies can be used in cities to empower citizens by adapting these technologies to their needs, rather than adapting their lives to the requirements of technology. The relationship between objects will change the design of industrial processes and automation. Internet of Things with various technologies including machine-to-machine communication provides more creative product and service delivery and efficient use of scarce resources and it is necessary for politicians to have clear aspirations and prospects for the development of IOT and the use of its services in order to smart cities.

Since human beings, directly or indirectly, are the main subject of intelli gent environments, hence all aspects of the smart city need to consider the human aspect. The recent boom in IOT makes smart city making a reality. In this research were studied the main components for smart city development, as well as were discussed the challenges of the smart city and were proposed a series of research paths. Researchers often understand the concept of smart city, but in this paper for a better understanding, through analysis component and applied field , a methodology was presented for people interested in research in this field. In this article, Smart City is defined as an integrated system of technology infrastructure that relies on advanced data processing and machine-to-machine communication. Theexcthe research is to improve the quality of life of citizens, reduce living costs, make a more efficient city, have happier citizens, make a more successful business and a more sustainable environment that helps researchers realize and implement the smart city.

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