Cutting-edge 360-degree Virtual tours

360 Degree Virtual Tours are buzzwords today that find numerous mentions in diverse technical and business literature worldwide. But is the present technological ecosystem scalable and pervasive enough? And, most importantly, does it address the most pressing problems that industries worldwide are facing today?

With the global pandemic on the rise, the reachability of physical spaces has drastically reduced, and it is proving to be a major challenge for several industries and several lines of business. Experiencing physical spaces remotely and digitally is the need of the hour. Digitization does seem to be the obvious answer to the problem, and 360 Degree Virtual Tours seem to be the prima facie solution. However, such technologies can help craft viable solutions to the problem only if they become scalable, maintainable, pervasive, and highly democratized.

Contents

Rapid Introduction

The global pandemic, coupled with other factors, has caused drastic reductions in footfalls, sales and conversion ratios across many industries. Several lines of business have either been diminished in scale or have been shut down entirely. One of the peak reasons for this is the limited reachability of physical spaces.

In addition to limited physical reachability, the other major factors affecting several industries today stem from an over-dependence on people and traditional processes.

Solving such modern business problems, especially those that arise due to limited physical reachability, often involves using many cutting-edge immersive technologies in a seamless combination. This is applicable for several industries and apt across different value chains.

Immersive technologies encompass a wide range of areas, including:

- Augmented/virtual/mixed reality
- 3D computer graphics
- Computer vision and image processing
- Machine learning/deep learning
- Voice/chat AI
- IoT

As advanced immersive technologies inch closer towards the stage of democratization, the adoption of such technologies to solve complex business problems is set to go through an increasingly upward trend in the near future. Immersive technology adoption is poised to see the highest growth, especially in scenarios where physical reachability is challenging.

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The global pandemic has resulted in reduced sales and conversion ratios across industries and lines of business.

One of the major reasons is the limited reachability of physical spaces

Solutions to modern business problems require a combination of various technologies.

Immersive Technologies encompass a wide range of areas – AR/VR to IoT.

Immersive Technology adoption is set to see an upward trend, especially for scenarios where physical reachability is a challenge.

Current trends and pervasiveness of XR technologies

XR and other related immersive technologies have greatly evolved over the past few years through advancements in 3D computer graphics, computer vision, deep learning, and other related fields.

The adoption of XR is picking up a significant amount of pace, thanks to the recent advancements in mobile devices and wearable

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Immersive tech has greatly evolved through advancements in 3D graphics, CV, DL, etc.

head-mounted devices. Such devices are now equipped with cutting-edge hardware: GPUs, processors, and co-processors that can simultaneously crunch millions of polygons and process complex neural networks.

In addition to advancements in hardware and software, the introduction of 5G comes with a promise to lean down bulky XR applications by letting them stream immersive 3D content (instead of hosting the content on-edge).

Advancements in mobile hardware are boosting XR adoption.

With 5G, XR apps can become leaner by enabling real-time content streaming

> "The number of announced 5G devices continues to grow rapidly, this month exceeding the 700 mark for the first time to reach 703 announced 5G devices. This is more than 25% higher than the number of announced devices at the end of Q4 2020 and an increase of 11.9% over the last month alone. Meanwhile, the number of 5G devices understood to be commercially available has risen by more than 28% over the last quarter, now standing at 431 commercial 5G devices, which represents 61.3% of all announced 5G devices.
>
> 153 operators have already launched commercial 5G networks in 64 countries/territories."

Source: Global Mobile Suppliers Association

However, the XR industry has numerous challenges of its own.

One of the key challenges that the XR industry has been facing for quite some time is sourcing/producing 3D content. Much of the 3D content required for immersive experiences is still mostly produced manually (except a small subset of objects that can be 3D scanned and used). This manual production of 3D content often involves artists with specialized talent and a complex workflow to craft lifelike 3D models and experiences.

The tedious nature of the people and processes involved in generating 3D content has led several organizations to look out for better and cost-effective alternatives. One of such alternatives is 360-degree views of spaces.

One of the major challenges in the XR industry is the authoring of 3D content.

Manual content production requires specialized talent and complex processes.

Organizations are looking out for cost-effective alternatives, e.g., 360-degree views.
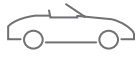
Challenges due to limited physical reachability

As mentioned earlier, physical reachability is one of the main challenges that industries worldwide are facing today. Let us consider a few examples.
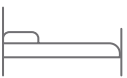
Real estate industry:

Lesser footfalls and reduced physical property visits

Auto industry:

Reduced footfalls in car showrooms

Hospitality industry:

Reduction in customer confidence (due to the pandemic), resulting in reduced customer visits.

Research labs and scientific establishments:

Difficulty in providing physical tours of facilities to different stakeholders

Manufacturing:

Difficulty in providing physical tours of facilities to different stakeholders

Healthcare tech industry:

Sales and marketing professionals finding it hard to provide physical product demos

Quick Read

Different industries face different problems due to a lack of physical access to spaces.

Primary problems include reduced footfalls, decreased customer confidence/retention, and decreased customer experience.

These problems cause reductions in sales and conversion ratios.

Such problems primarily result in the reduction of sales and conversion ratios. Let us consider the example of the **real estate** industry.

Modern-day property brokers rely heavily on digital means to enlist properties for sale, lease, or rent. Such listings typically include details such as:

Type of the property (Apartment, Villa, Studio, etc.)

Total area of the property

Property location

Property price

Age of the property

Images, snapshots, and/ or videos of the property

Images, snapshots, and/or videos alone may not be enough to instill the desired level of confidence in potential consumers to make informed decisions and finalize property deals. Virtual walkthroughs could be the solution to the problem. However, as of now, virtual walkthroughs are available for premium properties only.

As a result, interested customers usually connect with the broker separately and arrange for a physical visit to the property to experience it first-hand before they decide to close the deal finally.

However, there are multiple challenges with physical visits. To begin with, arranging a physical visit takes time, and both parties should agree to a common time slot that suits them. That becomes even more difficult if the broker and the consumer are geographically far apart from each other. Moreover, given the global COVID pandemic situation, physical visits are difficult and undesirable from a safety perspective. Additionally, most properties are almost totally closed to visitors following the pandemic. Open houses have been reduced, and physical visits have been curtailed.

With limited physical access to properties, combined with other factors, property brokers are now experiencing a decreased footfall, resulting in a gradual decline in the conversion ratio. Consequently, sellers are experiencing longer conversion times for property listings.

Circumventing the problem of physical reachability

Establishments and industries need to offer remote, immersive, and digitized tours of their physical spaces to alleviate the problems mentioned previously. Such digitized tours have the potential to:

- Transform businesses to require fewer physical visits
- Increase footfalls, sales, and conversions
- Improve customer experience and customer loyalty

However, there are multiple ways in which digitized tours can be authored, and the applicability of each method varies based on the situation and the organization's business goals.

Digitized Tours

2D Video-based Tours
Easy to capture
Immersiveness ★☆☆☆☆
Interactivity ★★☆☆☆

Full 3D Experiences
Difficult to author – requires specialized skills
Immersiveness ★★★★★
Interactivity ★★★★★

360-Degree Virtual Tours

360-Degree Video-based Tours
Requires specialized 360-degree camera to capture
Immersiveness ★★★★☆
Interactivity ★★★★☆

360-Degree Static Panorama-based Tours
Can be a mobile-based solution
Immersiveness ★★★★☆
Interactivity ★★★★★

Not all the methods are applicable everywhere. The applicability primarily depends on the existence or availability of the physical space in question. For example, labs that can be photographed can be covered through either 2D video-based tours or 360-degree virtual tours (both video as well as static). Whereas, in the real estate industry, model flats that don't exist physically can be imagined and toured through a fully crafted 3D experience.

Spaces with physical existence have the flexibility to be visualized through all the different modes of visualization depicted above. For such spaces, the balance between **immersiveness** and **ease of authoring** drives the choice of technology.

In this article, we specifically focus on **360-degree static panorama-based tours.**
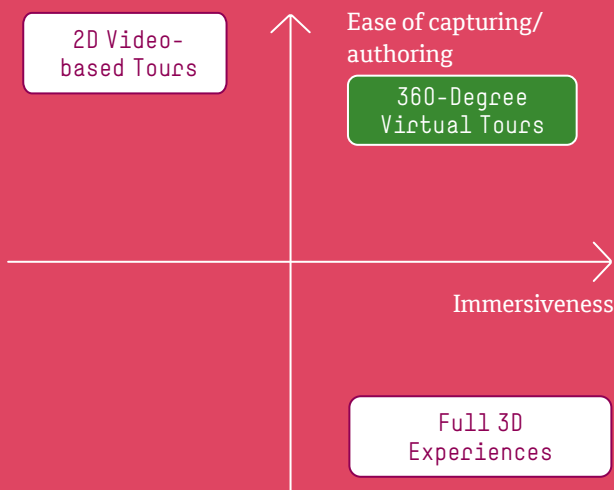
Quick Read

Digitized tours have multi-fold potential.

There are multiple ways in which such tours can be created.

The choice of technology depends on the availability of the physical space and the balance between immersiveness and ease of authoring.

2D Video-based Tours

Ease of capturing/authoring

360-Degree Virtual Tours

Immersiveness

Full 3D Experiences

Full 3D experiences offer true 3D spaces where the user can walk through and interact in a fully immersive manner. These 3D spaces can either be handcrafted, or 3D scanned using an advanced 3D scanner. However, building full 3D experiences is complicated and requires special 3D authoring skills. That is true regardless of whether the 3D spaces are handcrafted or 3D scanned*. 3D scanned spaces require a significant amount of post-processing time to clean up the raw scans and make them presentable.

Full 3D Experience
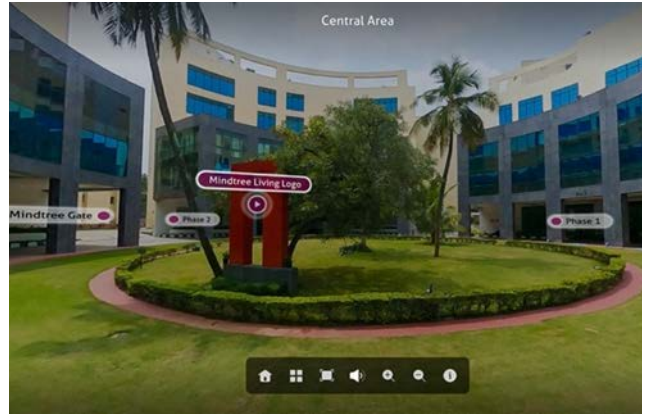
360-Degree Virtual Tour

Factors affecting widespread adoption of 360-Degree Virtual Tours

360-Degree cameras have existed for quite some time now and are being used in many places. As discussed above, 360-degree tours are either video-based or static panorama-based. Although there are several 360-degree cameras available in the market, 360-degree tours are still not pervasive enough. The widespread adoption is still a big challenge. There are several reasons for this

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360-Degree cameras have existed for quite some time now.

Widespread adoption of 360-degree tours is still a big challenge.

360-degree cameras typically produce **high resolution videos** which are often unsuitable to stream or play on many devices. Thus, 360-degree videos are throttled down to lower resolutions to make them playable on low to mid-range devices. This causes a significant loss in the quality of the video

Operating such 360-degree cameras **requires special experience**.

Requires complex pipeline to stitch individual photos into seamless 360-degree panoramas.

360-degree video/static walkthroughs **do not offer much interactivity**.

360-degree video/static walkthroughs **do not offer connected experiences**.

Most 360-degree tours **neither include annotations, nor waypoint-based navigation, nor any embedded rich multimedia content.**

Most 360-degree tours **do not work on simple phones and typically require high end hardware to render high resolution panoramas/360-degree videos**.

Making 360-Degree Virtual Tours more pervasive, immersive, usable, and scalable

Several components are required to bring virtual tours (and the authoring of virtual tours) to the fingertips of end consumers. The following are some of the key differentiating factors required to make 360-degree virtual tours more pervasive, immersive, usable, and scalable:

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Several components are required to bring virtual tours to end consumers

Some key differentiating factors are indispensable for 360-degree virtual tours to be successful.

Mobile first solution:

Virtual tours should be crafted keeping mobile phones in mind. Such mobile devices have limited hardware capability but, they are some of the most pervasive devices in the world.

Should be possible to capture with different types of cameras:

From sophisticated 360-degree cameras to simple mobile phones, catering to the novice and expert alike.

An annotation platform:

To enable users to annotate, activate and embed rich multimedia content as well as highly interactive waypoint-based navigation.

Seamless sharing & connectivity:

Consumers should be able to connect with other people and share the same setup/environment. This would enable multiple users to experience and share the same virtual space in real-time. This can be made possible through multiple channels and technologies - Twilio/Teams Integration, Video Calling, Shared VR.

A scheduler to schedule meetings:

To enable users to host meetings and immersive walkthroughs in shared, virtual 360-degree spaces.

Integration with CRM and other existing backend enterprise systems:

To make virtual 360-degree tours more seamless, scalable and accessible.

Recent advancements in technology and the rapid evolution of smartphones (and similar handheld devices) have made it even more feasible to realize the requirements mentioned above.Capturing 360-degree panoramas, which is one of the biggest challenges in crafting such virtual tour experiences, can be made more seamless, user-friendly, and pervasive through a combination of cutting-edge hardware and software.

Capturing 360-degree panoramas needs to be more democratized.

But, do today's handheld devices have what it takes to offer seamless capturing of 360-degree panoramas?

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Recent advancements in technology have made it more feasible to realize the require-ments to make 360-degree virtual tours successful.

Capturing 360-degree panoramas can be made more seamless through a combination of cutting-edge hardware and software.

The technological capabilities required on handheld mobile devices to facilitate the capture of 360-degree panoramas include (but are not limited to) the following:
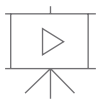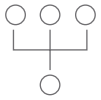
Audio-video/camera framework:

Accessing the device camera and setting the right set of parameters for panorama capture.
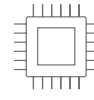
Geo-location:

To determine the current location of the user.

Sensor-fusion:

Combining readings from different device sensors, viz., the accelerometer, the magnetometer, and the gyroscope to interpret the device's orientation real-time.

Advanced GPU-accelerated 3D rendering:

Using 3D graphics and sensor data to guide the user to capture panorama images and rendering the captured panorama images in a spherical manner in real-time.

The whole process of capturing 360-degree panoramas can be brought on to handheld devices like smartphones and tablets, allowing the common mass to capture 360-degree panoramas, which was earlier available only with expensive and sophisticated 360-degree cameras.

The possibility of democratizing 360-degree panorama capture can be attributed to modern handheld devices, which have enhanced *audio/video, sensor-fusion, geo-location, and GPU-accelerated 3D rendering capabilities.*

As of March 2021,
- 100% of the iPhones in use support AR (through the ARKit framework) *
- 384 Android phones support AR (through the ARCore framework) **

These devices have all the features required to enable real-time 360-degree panorama capturing. Additionally, the number and percentage of such devices are only increasing.

Moreover, it is not only about being able to capture 360-degree panoramas. It is also about being able to render them, along with additional rich multimedia, interactive content, and animations. Modern handheld devices, backed by multi-core GPU-integrated chipsets, can prove to be more than capable of rendering such integrated, immersive experiences.

Source – Apple, iOS Device Compatibility Reference
Source – Google, ARCore Supported Devices

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Capturing 360-degree panoramas can be brought to handheld devices.
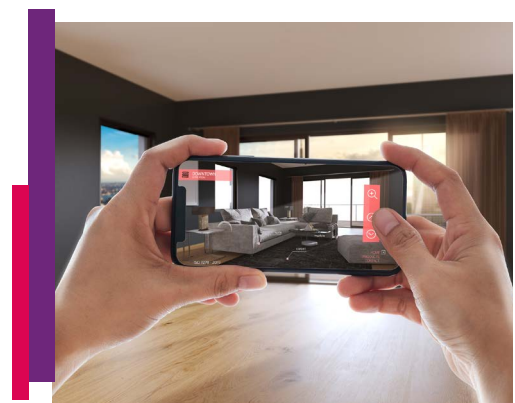
Possibility of democratizing 360-degree panorama capture can be attributed to the advanced features of modern handheld devices.

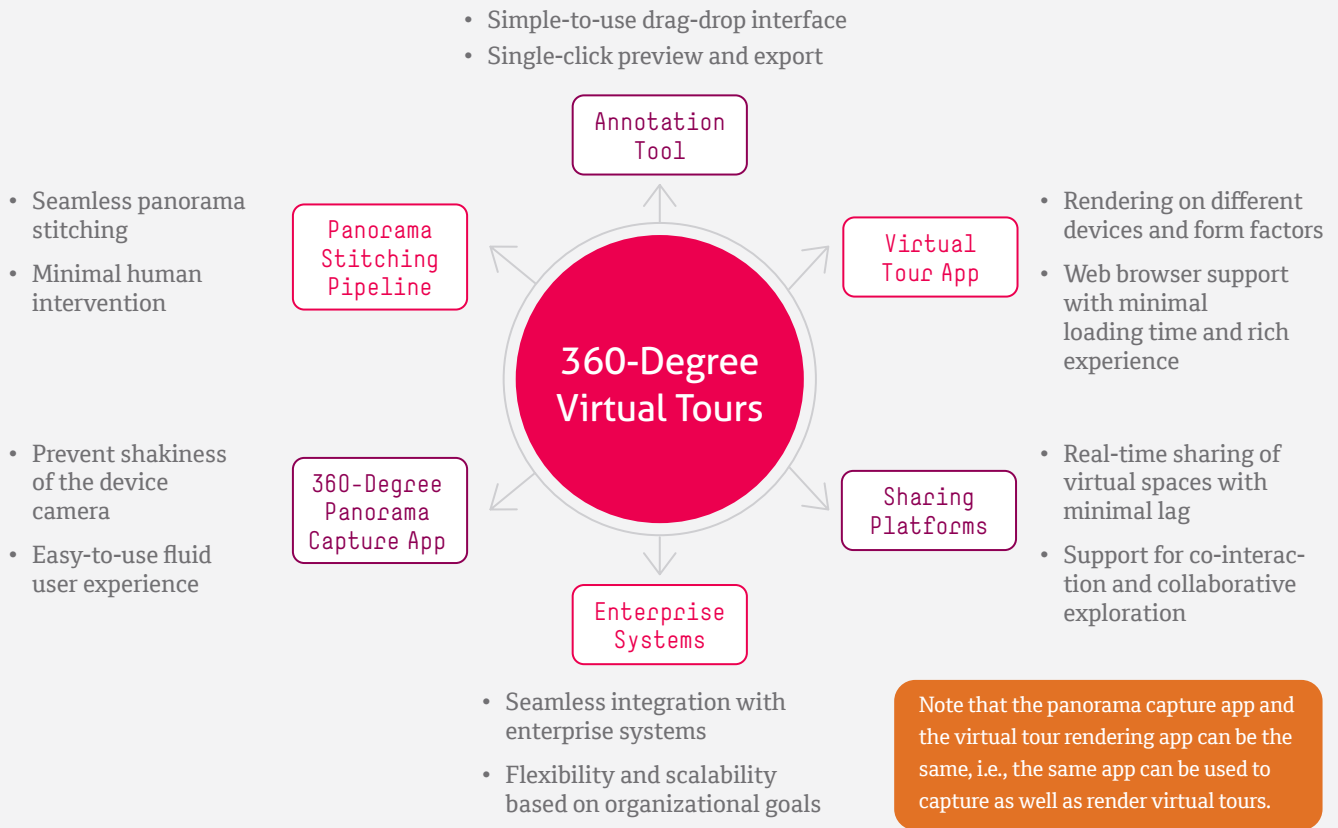The number and percentage of such powerful devices are only increasing.

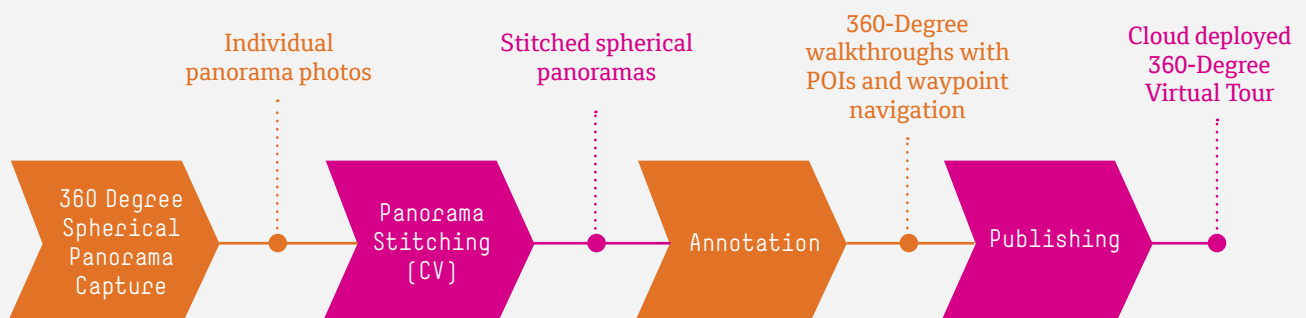The number and percentage of such powerful devices are only increasing.

The technical approach to realize 360-Degree Virtual Tours

Before taking a technological deep dive, it is essential to understand the components and the aspects that need to be addressed in the technical solution.

- Seamless panorama stitching
- Minimal human intervention

- Simple-to-use drag-drop interface
- Single-click preview and export

Annotation Tool

Panorama Stitching Pipeline

Virtual Tour App

- Rendering on different devices and form factors
- Web browser support with minimal loading time and rich experience

360-Degree Virtual Tours

- Prevent shakiness of the device camera
- Easy-to-use fluid user experience

360-Degree Panorama Capture App

Sharing Platforms

- Real-time sharing of virtual spaces with minimal lag
- Support for co-interaction and collaborative exploration

Enterprise Systems

- Seamless integration with enterprise systems
- Flexibility and scalability based on organizational goals

Note that the panorama capture app and the virtual tour rendering app can be the same, i.e., the same app can be used to capture as well as render virtual tours.

Now, let us examine the technical pipeline depicting the overall flow, beginning at the capture (of panoramas) and culminating in the published virtual tour.

Individual panorama photos

Stitched spherical panoramas

360-Degree walkthroughs with POIs and waypoint navigation

Cloud deployed 360-Degree Virtual Tour

360 Degree Spherical Panorama Capture → **Panorama Stitching (CV)** → **Annotation** → **Publishing**

It should be re-emphasized that the biggest hurdle to the democratization of virtual tours is the dependence on sophisticated 360-degree cameras. As the first component in the pipeline, we introduce a simple and easy-to-use mobile app that allows consumers to capture panoramic photographs of the physical space seamlessly. It uses state-of-the-art motion sensing (through a combination of accelerometer, gyroscope, and magnetometer data) to guide the user to capture photographs in a sequential-spherical manner. Such a feat has been made possible thanks to the enhanced capabilities of modern smartphones, making them viable alternatives to sophisticated 360-degree cameras.

During the capture process, multiple vertical rows of photographs need to be captured. This can be a daunting task for several users, especially if they don't have access to tripod stands and if they have to resort to capturing all the photographs by hand. This problem can be further compounded if the user wants to capture multiple panoramas of the physical space.
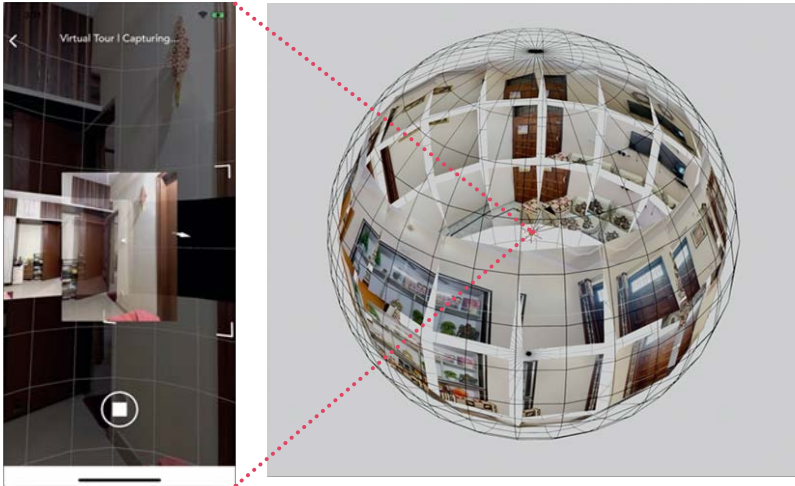
Thus, the capture process should be made as seamless as possible, especially from a user experience perspective. Fast and accurate photo capture (with minimal handshaking) is the key to a good panorama capture experience. One of the ways in which the capture process can be made less tiring and more entertaining is through **gamification**.

Capturing the individual photos (which would be used to create the spherical panorama) is just the first step in the entire process.

Once the individual panoramic photos get captured, they can be uploaded to the cloud, where a CV-based spherical panorama stitching tool can be used to stitch the photos together into seamless 360-degree panoramas. This stitching can be achieved through multiple techniques. Description of the individual stitching techniques is beyond the scope of this paper.

After the spherical panoramas are stitched, they can be pushed to an 'annotation tool,' which needs to provide a simple-to-use drag-drop interface to add annotations, rich multimedia content, and waypoint-based navigation to enable users to craft immersive 360-degree virtual tours.

As mentioned earlier, it is imperative that the virtual tour be 'shareable', i.e., it should allow multiple users to access the same digital environment simultaneously and in real-time. Now, there are multiple methodologies to achieve such immersive, real-time sharing –

```
                                    • Easy to integrate with existing
                                      enterprise systems (Teams,
          Sharing through video calls   Twilio etc.)
                                    • Requires more network
                                      bandwidth
  Real-Time Shared                 • Less interactive/immersive
  Virtual Spaces
                                    • Off-the-shelf solution to
                                      integrate with existing
                                      enterprise systems not available.
          Real-Time 3D sharing        Has to be custom-built.
          (Multiplayer-Game Technology) • Requires moderate network
                                      bandwidth
                                    • More interactive/immersive
```

Integrating virtual tours with existing enterprise systems is of utmost importance for better adoption and future scalability. Integration should be performed without disrupting existing ecosystems.

Let's continue with our example of the real-estate industry.

Let us suppose that a property broker/seller wants to post a property 'listing' on an existing property app/website with an intent to sell/lease out the particular property. A 360-degree virtual tour can then be added as part of the listing to attract potential buyers and influence their buying decision.

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Integration of 360-degree virtual tours should be done without disrupting existing ecosystems. This would lead to better adoption and scalability.

As mentioned earlier, listing a property requires many important pieces of information put together. A 360-degree virtual tour will be one of the missing pieces of the puzzle (as shown below).
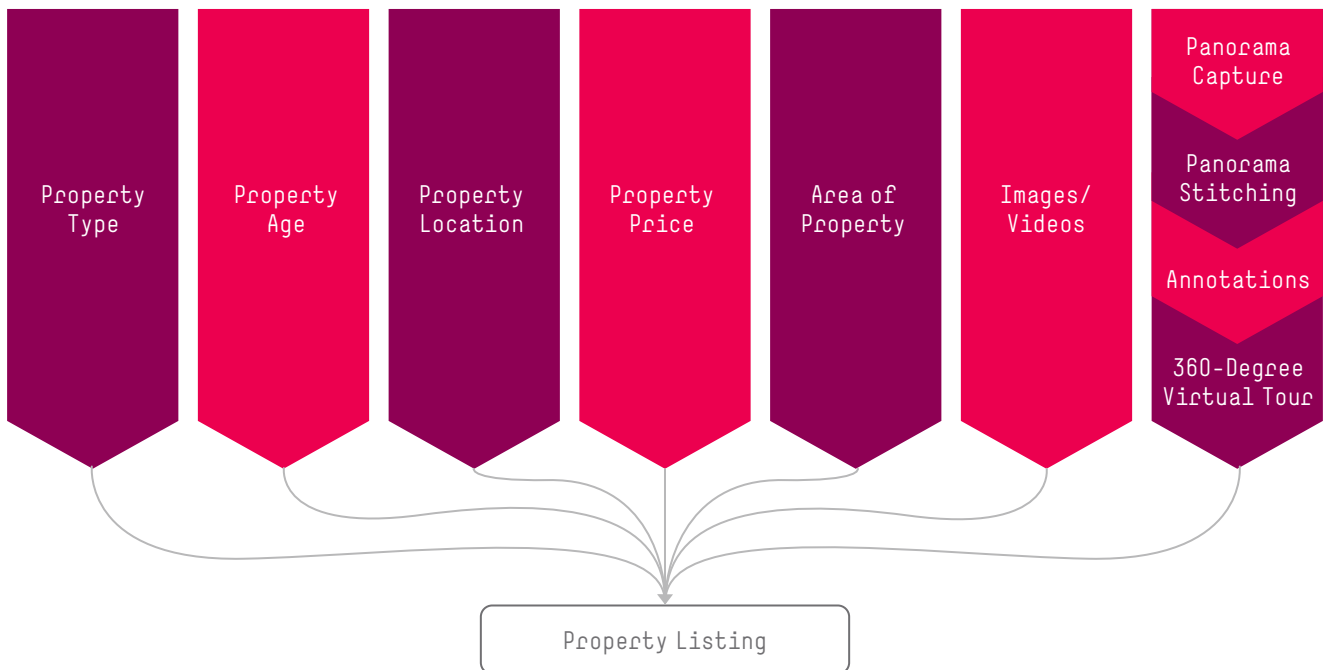
A careful and well-thought-through strategy should be employed to integrate virtual tours without disrupting existing ecosystems.

Aspects to take into consideration while crafting Virtual Tours

Several aspects should be taken care of while crafting virtual tours. These aspects affect the democratization of virtual tours, either directly or indirectly.
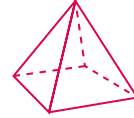
Would it cater to devices with varying processing power, screen size, aspect ratio etc.?

Would it run seamlessly on different browsers (and operating systems)?

Virtual tours need to be optimized to run on different browsers through lazy-loading, prefetching and caching mechanisms.

Apart from capturing panoramic photos, special attention needs to be given to the rendering of 360-degree virtual tours as well. Rendering should be fast and qualitative. It should not require high-end GPUs and should provide satisfactory results on mid to low end GPUs as well.

Benefits and how to reap them

There are several benefits that 360-degree virtual tours can offer, and comprehensive steps are required to reap the benefits.

Better customer experience, customer retention; better sales and conversion ratios

How to achieve - Customers need to be educated and encouraged to use virtual tour experiences through targeted marketing, continuous improvement and gamification.

Faster time-to-market

How to achieve - Through meticulously crafted user experiences, 360-Virtual Tours have the potential to offer much faster time-to-market as compared to full 3D experiences

Works on low-end as well as high-end devices

How to achieve - Through the use of lazy-loading, prefetching and caching mechanisms, virtual tours have the potential to cater to devices with varying processing powers.

Conclusion

360-Degree Virtual Tours have the potential to evolve into highly democratized, immersive, and scalable solutions. Through a meticulous and well-thought-through strategy, such tours can be realized with better market penetration, user adoption, customer experience, and retention. As devices, platforms and ecosystems continue to grow and evolve, such rich and immersive experiences are only going to become more and more pervasive in the near future.

Reference Architecture

Mobility

Sensor Fusion [Gyroscope/ Accelerometer/ Magnetometer]

360-degree image capture

- Device Motion Tracking (CoreMotion/Sensor Manager)
- UI Framework (UIKit/Ui SDK)
- Render Engine (SceneKit / Sceneform)
- Push Notifications
- Camera Module (AV Framework)
- Network Module

1. Capturing the 360-degree panorama and uploading to the server.
2. Displaying the resultant 360-degree experiences.

Webserver

CV / **Interaction Design**
- Image Correction
- Prefab Module
- Image Stitching
- WebGL
- Image Publishing
- Experience Serializer & Publisher

- Push Notification Services
- Web Services

1. Stitching the content and interaction together to create interactive immersive walkthroughs

Backend

- Validation Module
- Content Management
- Content Publishing
- DB Server
- DB

DB Queries, Tables, Schema, Views

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As the lead architect for AR/VR in Mindtree, he is responsible for the research, innovation, conceptualization, and design of platforms, solutions, and services leveraging cutting-edge immersive technologies. He has worked on multiple different technologies and industry verticals with 11+ years of wide-spectrum experience in the IT industry. He is also a US patent holder on Holography.

About Mindtree

Mindtree [NSE: MINDTREE] is a global technology consulting and services company, helping enterprises marry scale with agility to achieve competitive advantage. "Born digital," in 1999 and now a Larsen & Toubro Group Company, Mindtree applies its deep domain knowledge to 260 enterprise client engagements to break down silos, make sense of digital complexity and bring new initiatives to market faster. We enable IT to move at the speed of business, leveraging emerging technologies and the efficiencies of Continuous Delivery to spur business innovation. Operating in 24 countries across the world, we're consistently regarded as one of the best places to work, embodied every day by our winning culture made up of over 27,000 entrepreneurial, collaborative and dedicated "Mindtree Minds."