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Applications of Augmented Reality and Virtual Reality

Summary

This report provides a summary of current fully deployed virtual reality (VR) and augmented reality (AR) technologies being used in industry. Some of these technologies may be suitable for forest industry operations and training. VR is a simulated experience that can be similar or completely different from the real world and is most used to simulate dangerous work environments to meet training needs. VR is presented inside a headset where the user can no longer see the physical world around them. In contrast, AR provides information overlaid on the real-world scene. AR is an interactive experience of a real-world environment where the objects that reside in the real world are enhanced by computer-generated images. To view AR, you need to look through a device such as a smart phone, tablet, or headset.

Krystal Thompson, Brionny Hooper, Aliesha Staples and Richard Parker

Introduction

One project in the Human Factors programme of "Forestry Work in the Modern Age" is exploring current fully deployed virtual reality (VR) and augmented reality (AR) technologies that may be suitable for forest industry operational training.

Projects, hardware, and companies which have created virtual or augmented reality content for various industries are summarised in this report. This includes examples of fully deployed applications and prototypes. Applications and tools that enhance professional understanding are explored in the section 'On-the-Job Learning and Training'. VR is most used to simulate dangerous work environments to meet training needs, while AR provides accessibility to apprenticeship training on the work site.

'Augmenting Human Abilities/Perceptions' explores both VR and AR applications used to influence the user's behavioural responses and enhance their perceptive capability. 'Guided Maintenance' describes AR applications that are used to guide the user's action based on embedded professional knowledge, as well as allowing enhanced communication.

Augmented Reality

AR is an interactive experience of a real-world environment where the objects that reside in the real world are enhanced by computer-generated perceptual information, sometimes across multiple sensory modalities, including visual, auditory, haptic, somatosensory, and olfactory. AR overlays real world information in real time using tablets and head mounted displays with pre-installed information or live connection to experts who provide instruction. To view AR, you need to look through a device such as a smart phone, tablet, or headset.

The tablet and smart phone devices we all carry on us can be used in various industries to help improve the quality of communication and learning within workspaces. Being able to overlay information onto spaces and equipment can be a valuable resource in improving work safety, productivity and reducing the time needed with expensive equipment. The biggest limitations to these applications are signal connectivity, which is being consistently improved upon.

Head-mounted AR displays are currently not ready for industry use. They need charging often, are not dust or waterproof and are expensive ($5,000+ per device). One product likely to be made more commercially available is the Hololens – though there are limitations. The headsets are very fragile, cumbersome, and uncomfortable to wear. The field of view is small with restricted peripheral vision, and low quality, semi-transparent graphics.

Virtual Reality

VR is a simulated experience that can be similar or completely different from the real world. Applications of virtual reality can include entertainment (i.e. video games) and educational purposes (i.e. medical or military training).

VR is presented inside a headset where the user can no longer see the physical world around them. Because the user needs to invest in the head-mounted display (HMD) to access the content, VR has a larger barrier to entry than AR. The headsets have become easier to access with more hardware suppliers and reducing cost of HMD ($299 is an entry price). The immersive qualities of VR lean it towards training and high-risk high cost work environments such as medical, aviation, military, and forestry. In VR,

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learners can investigate environments digitally that within their physical environments may be dangerous or expensive to navigate.

VR is an artificial environment designed and created with software and presented to viewers in such a way that the user suspends disbelief and accepts the environment as their physical environment. VR is primarily experienced through sight and sound. As the hardware is developed, haptic feedback (touch and vibration) is being introduced. Originally designed as an entertainment tool, VR is currently going through rapid advances and the technology is establishing itself as a valuable and effective means of training.

VR allows applications to remove risk and reduce cost and delays when training staff while creating a consistent training environment. It is becoming more cost effective and safe to use. Table 1 contains a concise analysis of the opportunities and limitations of VR technology.

Table 1. Analysis of the medium and application of VR.

<table>
<tr><th colspan="6">Strengths</th></tr>
<tr>
<td>Cost Effectiveness
While the initial cost for development and hardware is mid-to-high range in comparison to traditional training materials, the returns on investment of VR training are immediately noticeable. These cost findings are found in the speed and consistency of training employees, along with access to expensive equipment and lower numbers of injuries or incidents.</td>
<td>Highly Immersive Training
The benefits of fully immersive training environments have been shown to outweigh the lower cost of traditional training. This is trackable through data and analytics with lower incidents when VR training is adapted.</td>
<td>Consistency
The training is constant across all languages and learning ability. For example, an employee cannot continue past a point in VR training without understanding the task. It is a different form of testing than theory-based learning where a person can potentially guess an answer – VR requires the trainee to physically perform the task.</td>
<td>Increased Safety for High Risk Training
Training people in high risk tasks creates hazards. The ability to train employees safety in tasks such as working at heights, forestry, firefighting, mining, and driving, enables the same level of immersion as physical training and replicates the emotion and real-world risks of completing the task wrong. E.g., at heights you can fall in VR, or in electrical work you can create a haptic response if a task is completed incorrectly.</td>
<td>Engagement with Training
Correct training requires repetition of task to create both mental and muscle memory. This repeated exposure cannot be gained by PowerPoint presentations or without access to the required equipment to perform the task. Improvement of engagement ultimately leads to better training outcomes.</td>
<td>Data Recording
The ability to see, hear and watch everything the trainee does in the training and obtain the data showing where they may need remedial help is a strength for VR. VR has higher interaction fidelity recording decision-making metrics, motor skills and attention paid.</td>
</tr>
<tr><th colspan="6">Weaknesses</th></tr>
<tr>
<td colspan="3">Immaturity of Technology
Despite VR being adapted into business models, it is still relativity immature. It has some limitations like frame rate, refresh rate and resolution, that are getting better, but photorealism is not yet fully available. The brain does become tricked by the virtual world, but the user is still relatively aware they are not in an actual physical environment.</td>
<td colspan="3">Technology Barrier
VR is seen as a new tech and with this comes hype and dismissal in equal measures. New technology needs to be proven before it can be implemented, but it needs to be implemented to be proven. Therefore, it takes a forward-thinking company to realise the power of an unproven technology and apply it.</td>
</tr>
<tr><th colspan="6">Opportunities</th></tr>
<tr>
<td colspan="3">Increase in Tracking and Hardware.
VR is integrating more sensors (smell and haptic technology) to improve the immersion capacity. This is making the divide between real and not real even smaller.</td>
<td colspan="3">Exposure Therapy
VR is helping with mental preparedness and this is helping reduce the possible emotional and psychological distress endured after harrowing experiences where PTSD can develop.</td>
</tr>
<tr><th colspan="6">Threats</th></tr>
<tr>
<td colspan="3">Limited Research on Results
There is little proven or completed scientific research into the benefits of VR for training. Some promising findings have been published, but the methodology thus far has not been validated or replicated extensively.</td>
<td colspan="3">Adverse Effects
People prone to motion sickness and with some optic conditions are unable to use VR training without adverse effects, including nausea and headaches.</td>
</tr>
</table>

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On-the-Job Learning and Training

Medical Applications of AR

Inside MS is an AR educational tool for neuroscientists to educate patients and students on the evolution of multiple sclerosis in a patient. It is deployed on both the Hololens and tablets. Hololens is used at expos and demos as it is not financially viable to provide all neuroscientists with the headsets (similar to Figure 1). Tablets are more practical and cost effective for wider use. The tool has been hugely successful with patients understanding 3D models more than 2D spliced images of their brain. The tool is widely available to all clinics working with *Novartis Pharmaceuticals*.

Figure 1: Medical AR application

Allergic Asthma solves the problem of educating time-pressured doctors with a quick, engaging, and custom-designed application that rapidly builds greater understandings of the benefits of early phase intervention for allergy-induced asthma. This application is deployed in tablets and smart phones. Tablets are for the sales team to demonstrate the application to clinics in the use of the asthma medication. Phones are for the clinicians to access the application anywhere at any time. The tool is currently released as a successful commercial product. It is used daily by both the medical professionals and sales teams.

Medical Applications of VR

The *Neurologist Diagnosis Skill Training* is a tool for neurology students to develop their diagnostic skills using the HTC Vive VR device. The VR experience allows the user to talk to a digital patient face to face to discuss their symptoms in a repayable environment to improve information retention and learning. The feedback has been noted as extremely positive from student doctors using this approach.

Military Applications of AR

The *Augmented Reality Sandtable (ARES)* was developed by the US Army Research Laboratory as a training tool. It is to a low-cost method of geospatial terrain visualization. It is deployed using a 'Sandbox' AR projector and 'Sandbox' table (Figure 2).

Figure 2: Military AR Sandbox application

The 'Sandbox' technology has been successfully used in other applications such as wildfire command and control situational awareness. It allows users to create topography models by shaping real sand, which is then augmented in real time by an elevation colour map, topography contour lines and simulated water. The technology aims to tech concepts such as reading topography maps and the meaning of contour lines (Figure 3). AR has also been used to display animated terrain in military intervention planning.

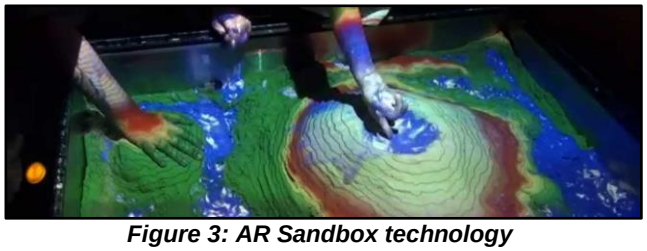

Figure 3: AR Sandbox technology

Aviation Applications of VR

The *JetStar VR Aviation Maintenance Training* simulation helps employees learn how to move, interact, and communicate in a hanger using Oculus Rift technology. Simulations were created for each process module studied with virtual descriptions and a final test performed by trainees. The platform provides a set of logs to evaluate the trainee's activities. This information helps tracking the learners progress and the knowledge transfer of the trainees.

Health and Safety Applications of VR

Created by the Finnish industrial machinery company, *Metso*, the Risk Observation Virtual Training system allows users to see and identify hazards displayed in 3D space on Samsung Gear VR equipment (Figure 4).

Figure 4: VR training technology

In a more realistic environment, *Barminco's VR Hazard Identification* tool allows its users to simulate the experience of underground mining on an Oculus DK2.

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Augmenting Human Abilities / Perception

Medical Applications of AR

The *Proprio Vision* application combines machine learning and AR to create precise 3D medical images viewed through a custom HMD (Figure 5). It helps surgeons to see obstructions to help enhance surgery plans. Currently being used in neuro- and orthopaedic surgeries in hospitals.

Figure 5: Proprio 3D AR medical imaging

Medical Applications of VR

Health care facilities are benefiting from the use of VR for distraction and monitoring patients. New Zealand company *StaplesVR* has applications used in the healthcare industry to improve the patients experience and reduce perceived pain. For example, *VRemedies* is a tool created for hospitals to provide exposure therapy to patients, allowing them to experience procedures before going into the real one such as MRI scanning which can be noisy and claustrophobic.

Military Applications of AR

The *U.S. Army Research, Development and Engineering Command's Communications-Electronics Research, Development and Engineering Centre (CERDEC)* have created a prototype utilising AR. The prototype, known as 'Tactical AR (TAR)' device, is a small (2.5 x 2.5cm) eyepiece that is mounted on a soldier's helmet (Figure 6).

Figure 6: Tactical AR device

The eyepiece overlays a map onto the soldier's field of vision, offering target information and GPS tracked data of their team. In 2014, the *Q - Warrior* AR head up display underwent field testing by the U.S. military (Figure 7). It was designed for better situational awareness, friend-or-foe identification, and the ability to coordinate a small unit even when away from their vehicles.

Figure 7: Q – Warrior battlefield head up display

The HUD 3.0 helmet-mounted AR display (Figure 8) was developed for U.S. Army soldiers to provide them with better night vision and tactical information in the form of an overlay. In addition, it has a targeting reticule that is wirelessly linked to the rifle showing where they are aiming and overlap of digital terrain, obstacles, and virtual foes.

Figure 8: HUD 3.0 helmet-mounted AR display

ARTopos is a 3D topographic map visualization mobile application combining analogue paper map planning and a digital routing service. This is a collaborative tool used during preliminary troop briefings.

Manufacturing and Construction Applications of AR

Australian steel company, *Bluescope*, and energy company, *Endeavour Energy*, are using the AR application 'Safety Compass'. Deployed on smart phones and tablets, 'Safety Compass' uses geo-tagged data to help ease the volume of information that is not readily available and ensure information is provided regarding obscured hazards. Instant information access and visual ques have resulted in increased safety through reduced accidents.

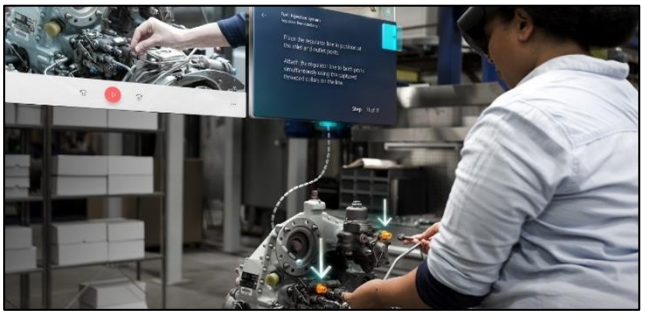

Figure 9: Hololens Fusion 360

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In 2015, *Microsoft* and *Autodesk* announced a collaboration to bring Hololens functionality into a software called 'Fusion 360' for industrial designers and mechanical engineers (Figure 9).

The Studio Manager of Microsoft Hololens claimed that this tool will mean more "…effective validation of 3D models – which could mean fewer physical prototypes."

In a 10-month development span, the *HoloLic: Thyssenkrupp Stairlift Solution* team have produced a commercial Hololens product that allows its users to improve their ability to sell and measure stair lift equipment. Using the Hololens depth sensing, measuring and 3D visual tools, they have reduced the wait times for stair lifts by six-weeks.

Sports Applications of AR

Figure 10: NHL Puck and Player Tracker

The *NHL Puck and Player Tracker* application follows every movement of the puck and each team's players during a game, detailing passes, shots and positioning precisely in real time. Fans can use their smart phones or tablets to also track player movement, speed, and time on the ice (Figure 10).

Retail and Marketing Applications of AR

There are many cases of the Hololens being used as a tool for 'previsualization' allowing customers, builders, and architects to see designs in full scale before they are brought to life. Some examples include *Lowe's Kitchen; Ikea Place; Coca Cola B2B*; and *Arena Media* – marketing AR platform.

Lowe's is a well-known U.S. retail company and the AR kitchen application was created by *Lowe's Innovation Labs*, and now exists in a showroom kitchen enabling physical objects to be blended with digital holograms.

The *Ikea Place* application lets people experience, experiment and share how design transforms any space using an overlay of true to scale, 3D products to aid buying decisions.

Coca-Cola B2B is an interactive AR experience where users can scan a coke can and witness one of 12 stories come to life on their smart phone. The creators involved used this to explore AR as a medium for emerging markets.

Applications of AR in Education

NASA have created a new mobile application, called Spacecraft AR, to produce virtual 3D models of *NASA* robotic spacecraft onto any flat surface with in-depth information about each mission.

Forestry Applications of AR

AR has been used to augment the operator's visual field (Figure 11) with measurements from the forest machine and its environment with encouraging initial results (Palonen, Hyyti & Visala, 2017).

Figure 11: AR research in forestry

Forestry Applications of VR

V-Forest (Figure 12) is a forest management tool viewed on HTC Vive equipment that allows forest owners to calculate the revenue prospects of logging activities (Holopainen, Mattila, Poyry, & Parvinen, 2020).

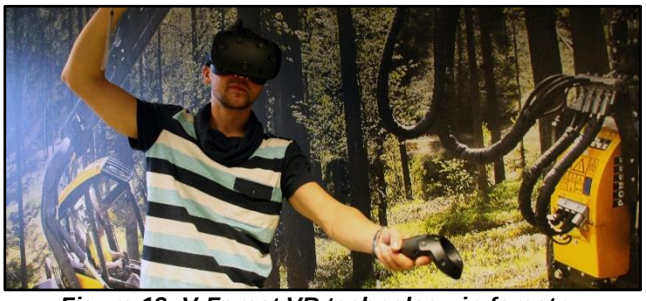

Figure 12: V-Forest VR technology in forestry

The same Finnish group has produced another application using Oculus Rift for users to assess forests and forest inventories in a VR environment with the same level of accuracy that would be achieved if they had gone to the forest themselves.

Guided Maintenance

Aviation Applications of AR

NASA engineers enlisted the help of the Microsoft Hololens to help assemble the crew capsule Orion without having to read thousands of pages of paper instructions. They reported that the wearability and ease of use still needs some improvement, but they see promise for the future. Both *Airbus* and *Boeing* have implemented case studies on using AR headsets to improve manufacturing efficiency.

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Manufacturing and Construction Applications of AR

Becton Dickinson, a manufacturing company for medical devices uses an AR application to share real-time maintenance information with machine operators (Figure 13). It is a custom application that improves operational efficiency by enabling operators to superimpose data onto a physical machine or piece of equipment. This application includes connectivity, mobility, cloud services and data analysis. This app is also being used in food manufacturing at *Buhler*, and in Steel manufacturing at *Tubular*.

Figure 13: AR in medical device maintenance

Using the Hololens 'Remote Assist', *Chevron* can help their frontline workers by offering remote connection with engineers. The Hololens can translate what they see in 3D space allowing for improved communication. *Chevron* is using this technology to help facilities management including oil refineries, lubricants plants, and offshore locations.

Figure 14: Automotive AR

Hyundai have developed an AR application that car owners can download to learn more about their vehicle (Figure 14). They can also perform simple maintenance tasks, such as oil changes and topping up wiper fluid, guided by the app. The smartphone application replaces instruction manuals and allows the user to simply point their phone at the car to view overlaid information. Similar technology has also been created by *BMW, Microsoft*, and *Genesis*. Information at the fingertips of customers and end users with access on everyday devices has resulted in less call centre demand.

Civil Engineering Applications of AR

Developed for *Network Rail* in Europe, this application solves the need for having different manuals for many complex mechanisms when doing maintenance jobs. The application is deployed via the Hololens (Figure 15). It provides workers with access to professional knowledge regardless of where they are located.

Figure 15: AR railway maintenance application

Conclusions

Tables 2, 3 and 4 include a full list of all technology, software and companies explored. These results demonstrate that VR and AR technologies offer new ways for the forest industry to enhance training and real-world operations. These technologies are very new, and advances are being made rapidly so it is accepted that this information will become dated. However, this report does provide forest managers with an overview of the breadth of uses and the types of technology available. Tasks requiring substantial experience and knowledge, such as maintenance could be a good first use of AR, especially as forest machine operator training simulators are already using VR systems.

Table 2: Examples of Virtual Reality by Industry

Name	Industry	Deployment	LINK
Risk Observation Virtual Training	Manufacturing	Samsung Gear VR	https://www.youtube.com/watch?v=wvfxlzV2mlc&feature=youtu.be
Hazard Identification for Miners	Mining	Oculus DK2	https://www.youtube.com/watch?v=7Qmr_-NS-JM&feature=youtu.be
Aviation Maintenance Training	Aviation	Oculus Rift	https://youtu.be/tVvVwqHy_r0
AR Neurologist Diagnosis	Medical	HTC Vive	https://www.hatchaustralia.com/novartis-charcots-room-1
VRemedies	Medical	HTC Vive, Samsung GVR	https://www.staplesvr.com/vremedies
V-Forest	Forestry	HTC Vive	https://forest.fi/article/virtual-reality-to-boost-forest-management/
VR for Forest Inventories	Forestry	Oculus Rift	https://forest.fi/article/virtual-reality-to-boost-forest-management/

Table 3: Examples of Augmented Reality by Industry

Name	Industry	Deployment	LINK
Inside MS	Medical	Hololens and Tablet	https://www.youtube.com/watch?v=C4_PgRoVXhs
Allergic Asthma	Medical	Tablets and Phones	https://youtu.be/Jq4eyLLPFZY
ARES - AR Sand Table	Military	Sandbox Projector	https://www.researchgate.net/publication/282816904_The_Augmented_REality_Sandtable_ARES
AR Sandbox	Museums	Sandbox Projector	https://youtu.be/CE1B7tdGCw0
AR Military Animated Terrain	Military	No known deployment	https://www.youtube.com/watch?v=FdC-PRmNcRs&feature=youtu.be
AR for Machine Operators	Manufacturing	Tablets and Phones	https://www.youtube.com/watch?v=KQsPXwvXDBY&feature=youtu.be
AR Hazard Identification	Construction	Tablets and Phones	http://www.thesafetycompass.com.au
Remote Assist	Construction	Tablets and Phones	https://www.youtube.com/watch?v=rbL8H2lyC8Q&feature=youtu.be
NASA Hololens Project	NASA	Hololens	https://www.technologyreview.com/s/612247/nasa-is-using-hololens-ar-headsets-to-build-its-new-spacecraft-faster/
Airbus and Boeing AR	Aviation	Hololens	Boeing :https://www.boeing.com/features/2018/01/augmented-reality-01-18.page Airbus:https://www.engineering.com/AdvancedManufacturing/ArticleID/14634/Airbus-Uses-Smart-Glasses-to-Improve-Manufacturing-Efficiency.aspx
Automotive AR	Automotive	Tablets and Phones	https://www.youtube.com/watch?v=qOMvl6-cP7o
AR Railway Maintenance App	Railway	Hololens	https://4experience.co/portfolio-item/hololens-training-maintenance-demonstration/
Fusion 360	Manufacturing	Hololens	https://blogs.windows.com/devices/2015/11/30/microsoft-hololens-and-autodesk-fusion-360-collaboration-that-could-radically-change-the-product-design-industry/#36g4Hiw7lPYTCrWJ.97
HoloLic	Healthcare	Hololens	https://www.zuehlke.com/ch/en/success-stories/hololinc-faster-delivery-customer-experience/
Forestry Research Paper	Forestry		https://pdfs.semanticscholar.org/b410/aa77d30d5d0046c357d3aeee7dc475f9e314.pdf
NHL Puck and Player Tracker	Sports	Tablets and Phones	https://www.youtube.com/watch?v=OdJsmaNJqkw&feature=youtu.be
TAR	Military	Custom HMD	https://www.youtube.com/watch?time_continue=94&v=x4MmIJytGJQ&feature=emb_logo
Q Warrior	Military	Custom HMD	https://www.youtube.com/watch?v=Ci_IZ3Q8qnA
HUD 3.0	Military	Custom HMD	https://www.youtube.com/watch?time_continue=94&v=x4MmIJytGJQ&feature=emb_logo
ARTopos	Military, Recreation	Tablets and Phones	https://dl.acm.org/doi/pdf/10.1145/3123024.3124446
Lowe's Kitchen	Retail	Hololens	https://www.youtube.com/watch?v=m8DXtmrGXHQ
IKEA Place App	Retail	Tablets and Phones	https://newsroom.inter.ikea.com/gallery/video/ikea-place-demo-ar-app/a/c7e1289a-ca7e-4cba-8f65-f84b57e4fb8d
Coca-Cola B2B App	Retail	Tablets and Phones	https://www.thedrum.com/news/2019/09/10/coca-cola-embraces-augmented-reality-with-interactive-experience
Spacecraft AR	Education	Tablets and Phones	*https://www.nasa.gov/feature/jpl/new-ar-mobile-app-features-3-d-nasa-spacecraft*
Arena Media	Advertising	Tablets and Phones	https://arenavirtualmedia.com
Proprio	Medical	Custom HMD	https://www.propriovision.com/technology

Table 4: Examples of AR and VR Technology by Supplier

Name	Image	LINK
Hololens 1st Generation		https://docs.microsoft.com/en-us/hololens/hololens1-hardware
Hololens 2nd Generation		https://www.microsoft.com/en-us/hololens/hardware
Magic Leap		https://www.magicleap.com/en-us
Apple Tablets 2019 Edition +		https://developer.apple.com/augmented-reality/
Android Tablets 2019 Edition +		https://arvr.google.com/arcore/
Apple and Android Phones 2018 +		
HTC Vive		https://www.vive.com/nz/
Oculus Rift		https://www.oculus.com/
Samsung Gear VR		https://www.samsung.com/global/galaxy/gear-vr/

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