Motion capture buyer's guide for life sciences

VICON

Contents

Motion capture buyer's guide

1

Key terminology

For the basics, you'll need to know the following key terms:

CAPTURE

The recording of data from all devices within the system, for example, camera data, analog data (EMG/force plates) and video data

CENTROID

The 2D coordinates and radius of the marker detected by the camera sensor

EXTRINSICS

Information about the camera position relative to the world

INTRINSICS

Information about the lens, such as its focal length and radial lens distortion

LABELING

Assigning a label/name (either manually or automatically) to a reconstructed marker

MARKER CLOUD

The array of 3D reconstructions that are made from the marker set worn by the subject

MODEL

Mathematical outputs, such as kinematic and kinetic model outputs, obtained from anatomical information

MODELING

Using mathematical formulae created by the vendor or by the user, in languages such as C#, Python or MATLAB, to produce outputs from anatomical data

OBJECT(S)

Single-segment, rigid body, which is captured by the system

RECONSTRUCTING

Using an algorithm to convert 2D camera data into 3D marker data

SUBJECT(S)

The physical entity whose motion is being captured or analyzed by the system, for example, a person

SYSTEM

The entire setup that includes cameras, software, computer and other equipment, such as force plates or EMG

TRACKING

Using an algorithm to detect the object (marker) and follow (track) the path of the object

VOLUME

The three dimensional space (LxWxH) within which cameras track subjects (often smaller than the size of the room, as the equipment takes up space around the outside of your lab)

2a

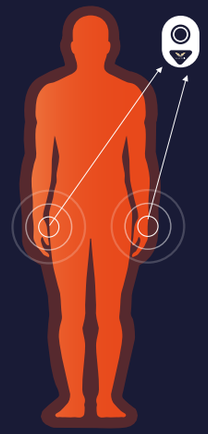
Ways to capture

Motion capture (mocap) is the general umbrella term for a wide range of technologies that allow you to capture and analyze motion.

This explains the key features of the most commonly used types of motion capture system.

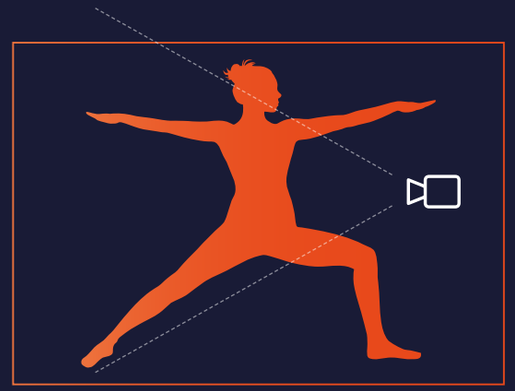
OPTICAL-PASSIVE

- A camera emits a specific wavelength of light from a built-in strobe
- The strobed light bounces off reflective material and is picked up by the same camera's sensor
- The 2D centroid positions of markers are sent to the software from multiple cameras for calculation of the 3D positions
- The software identifies and labels the markers
- Some high-end cameras perform additional signal-processing on these centroids



OPTICAL-ACTIVE

- Active markers are a light source, which may or may not be synchronized with the motion capture system and require a local power supply
- The light source is picked up by the camera's sensor



VIDEO MARKERLESS

- Video cameras capture subjects without using markers
- There are many different types of cameras that can be used, including webcams, machine vision and SDI
- Video from all cameras is captured synchronously
- The video is then used to automatically detect subjects' skeletal landmarks by using artificial intelligence
- The collected data is further processed and made available for analysis

INERTIAL

- Inertial measurement units (IMUs) contain accelerometers, gyroscopes, and magnetometers to measure the forces exerted by and on the subject
- IMUs are attached to the subject
- Inertial data can be recorded to onboard memory, via Bluetooth, Wi-Fi or bespoke RF transmission

2b
Calibration

All measurement systems require calibration, and in some cases, a calibration of the utilized mathematical model.

Calibrate passive and active optical cameras with an object of known measurements with markers at known locations. Wave the object, covering as much of each camera's field of view as possible, to give the system information to create the measurement volume.

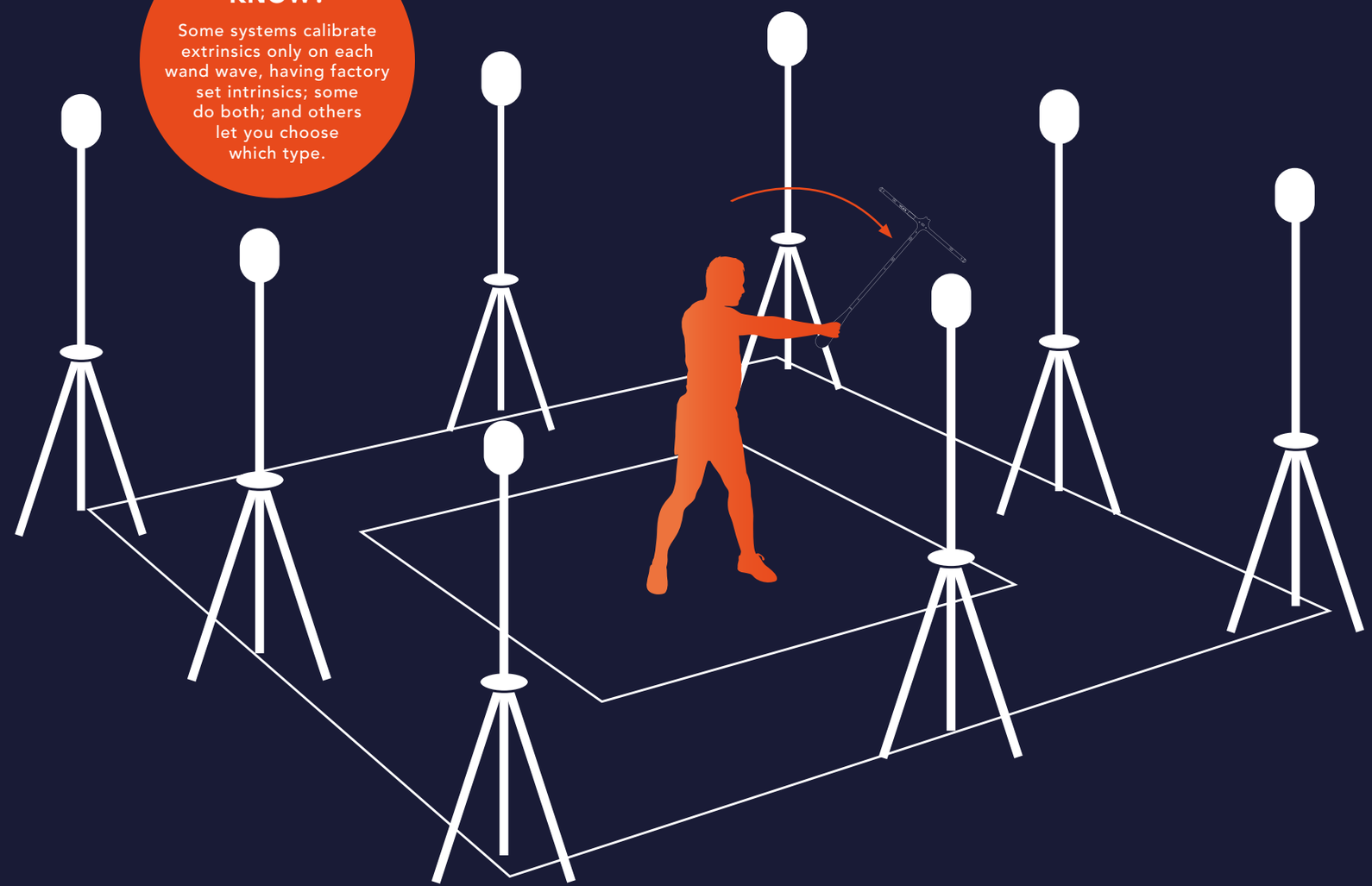
Lens optics, digital sensors and operating electronics all have optimum running temperatures that can be affected by temperature outdoors, air conditioning or heating. Changes in internal operating temperature can affect their intrinsic calibration.

Markerless motion capture systems require video camera calibration. Some can use the same method as optical systems (above), some require geometrical calibration (checker board).

IMUs can be calibrated to a global axis to match each other or another system, such as an optical one.

DID YOU KNOW?

Some systems calibrate extrinsics only on each wand wave, having factory set intrinsics; some do both; and others let you choose which type.



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Types of motion capture

1. OPTICAL-PASSIVE

OVERVIEW

Most flexible and commonly used method.

WHAT DOES IT CAPTURE?

The position of the markers, attached to any subject and/or object, as they move throughout the 3D capture volume.

PROS

- Highly precise systems
- Markers are small and light so movement remains natural
- Capture movement inside or outside and in small or large spaces
- Predefined or customizable marker sets can be used: from sets based on anatomical placement to cluster sets
- Captures small and complex body movements such as feet, face or fingers
- Large numbers of markers and subjects can be captured simultaneously
- Well-established and validated integrations with third-party lab equipment (e.g. force plates, EMG, etc.), and other motion capture technologies (e.g. inertial, active, video)
- Many years of clinical validation and research exist

CONS

- As the passive marker contains no ID in itself, it requires labeling either by a computer aided algorithm or human hand
- Markers require securing to ensure they remain in position throughout the motion to be captured
- The distance seen is a combination of camera specification and marker size used
- The technology is inherently looking for reflections of light, ideally only those provided by the markers. However other "noise" can be seen such as those within the IR/NIR regions of the camera strobes, or reflections from mirrors and shiny floors *(these can be overcome by using technologies that can adapt to noise)*

IDEAL FOR...

Biomechanical and clinical settings where highly advanced, accurate and precise levels of data are required – indoors or out

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Types of motion capture (cont.)

2. OPTICAL-ACTIVE

OVERVIEW

A variety of active markers are available; some synchronized, some with embedded labeling, some sequenced. In general terms, 'active' simply means replacing the passive marker with an electronic device that emits from a single or multiple LEDs a specific wavelength of light to be seen by a range of cameras in the same way as passive markers.

WHAT DOES IT CAPTURE?

In the same way as Optical-Passive, captures the position of the active markers attached to any subject and/or object, as they move throughout the 3D capture volume.

PROS

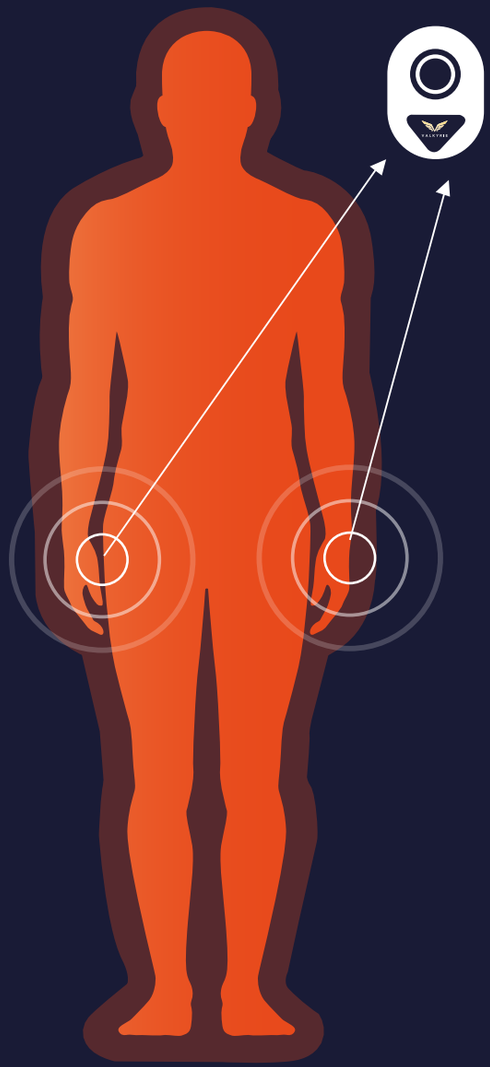
- As the marker is the point source of light, the distance achieved is greater vs passive, depending on the camera characteristics – lens and sensor
- If using a sequenced active marker system, only one marker is visible in any one frame making it near impossible to get the labeling wrong

CONS

- Higher marker cost
- Larger marker size and weight than passive markers
- Markers require power via wires and a power pack or internal battery
- Extra weight of active markers requires even further care when mounting to the subject

IDEAL FOR...

Long range motion capture



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Types of motion capture (cont.)

3. VIDEO MARKERLESS

OVERVIEW

Providing users with a method of measuring motion without the need to attach points of reference to the subject. Based on video technology, various algorithms generate relevant body points for analyzing motion.

WHAT DOES IT CAPTURE?

Human motion without the need of markers, in front of at least one camera, in general 6+ needed.

PROS

- Any measurement environment is possible
- Multiple objects can be tracked and identified synchronously
- Analysis data are created automatically
- Can wear ordinary clothing
- Freedom of movement

CONS

- Subject needs to be seen in each camera with a large proportion of sensor coverage for the best outcome
- Limited capability of size of tracking area and number of subjects and props at the same time
- Data processing requires high-end GPUs

IDEAL FOR...

When attaching markers is impractical

3

Types of motion capture (cont.)

4. INERTIAL

OVERVIEW

Self-contained small units that allow users to leave the lab.

WHAT DOES IT CAPTURE?

Meaurements can include MEMS (Micro Electro-Mechanical System) sensors such as acceleration (g), gyroscopic data and magnetometer.

PROS

- Long data sessions
- Not constrained to camera volumes
- Inexpensive way to access measurement data
- Some IMUs have onboard memory, meaning they can continue to record beyond a control device
- Lightweight and compact – can often be used with a smart device/app

CONS

- Only tracks its own movement and relative to another sensor, not its absolute position in space (unless GPS included)
- Calibrate at the start of each session, as there can be data drift
- Needs power supply, so cost, weight and size are greater than reflective markers
- Low-g sensors can over-saturate on high-intensity movements

IDEAL FOR...

Measuring where a confined volume is not practical, like running a marathon

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System specification

What system specifications should I care about when starting my search?

RESOLUTION

A higher resolution camera can calculate the center of a marker (centroid) more precisely at the same distance compared to a lower resolution camera, and can track the same size marker at a greater distance.

Lower resolution may produce larger errors because there are fewer pixels from which to calculate the marker centroid.

FRAME RATE

The camera frequency or frame rate is a measure of how many frames of data are captured per second (FPS or Hz).

The faster your subject moves, the higher the frame rate should be. Most human movement can be adequately captured at 120 FPS, but higher frame rates might be helpful for tracking very fast motions like throwing or swinging a golf club.

A higher frame rate can increase the potential for capturing a specific event, such as ball contact.

4

System specification (cont.)

What system specifications should I care about when starting my search?

MARKER SIZE (in millimeters)

What size markers will work best for your application?

Full-body markers are typically 14 mm in diameter.

Small markers are used for detailed capture associated with a segment, for example, hands.

LAB SIZE

The size of your lab will often dictate your capture volume space and what camera resolution you might need.

SYSTEM SOFTWARE

How would you like to process your data?

Are you looking for a turnkey system to provide complete kinematic and kinetic data?

Does the data need to be clinically validated?

Are you looking for marker positions to post-process in other software, such as Visual 3D, MATLAB, etc.

Different software packages have different post-processing and reporting capabilities.

5a

Additional data: Inputs

You can add a range of equipment, and precisely synchronize the data into your motion capture system to complement the range of data it collects, enhancing your research capabilities.

INERTIAL SENSING TECHNOLOGY

To add data (not all sensors provide all measurements) on the acceleration, angular velocity and direction or relative position of the body and/or limb(s). The best sensors can be perfectly synchronized to optical motion capture data (optical motion capture can capture some of the above to compare the datasets).

VIDEO

To assist with qualitative review and analysis of motion (e.g., overlay of Ground Reaction Force vectors), prosthetic alignment, healthy and pathological gait, sporting activities, and symmetry or asymmetry patterns, as well as providing an ongoing visual for the clinician / researcher / participant for treatment planning or sports performance / technique improvement.

GENERIC ANALOG

Any device that outputs a voltage signal (+/- 10 V) on a wire/cable can be integrated (e.g., electrogoniometer, audio, timing gates, etc). Also, for third-party equipment that can't be directly integrated with the motion capture system, synchronization pulses can be sent to align the independent data for post analysis.

GENLOCK / TIMECODE

External video synchronization.

EYE-TRACKING DATA

The real-time observation of participants' gaze data provides quick and actionable insights. Eye-tracking systems may be synchronized with motion capture systems.

ELECTROMYOGRAPHY (EMG)

Electrical impulses of muscle activity (synchronized to the motion capture data) during dynamic activities (walking, running, sports, pathological gait), to help determine muscle activation for the activity.

GROUND REACTION FORCES

Force platform systems or force transducers allow you to derive the forces, moments and powers within and across the segments and joints.

DIGITAL INTEGRATION

Newer hardware (EMG/force plates) allow for digital integration via USB, reducing the need for extra third-party hardware.

5b

Additional data: Outputs

You can also synchronize data that's been captured and modeled in your optical motion capture system to deliver the following outputs.

KINEMATICS

Spatial movements of the body including joint angles, displacements, velocities and accelerations. Kinematic data can be derived from optical or inertial motion capture systems.

KINETICS

The internal and external forces involved in the execution and control of movement e.g., measuring ground reaction force with a force platform.

EXTERNAL DEVICE OUTPUTS

All integrated equipment data.

BIO-FEEDBACK OUTPUTS

System acts as a hub to bring data in and out to control equipment such as treadmills (real-time and offline).

TEMPORAL PARAMETERS

Cadence (steps/min), Speed (m/s), Stride and Step length (m), Stride and Step time (s).

PLANTAR PRESSURE

Distribution of pressure and path of pressure progression via a pressure plate, mat, or insole.

TTL PULSE / SYNC OUT

Configurable 5-volt DC output.

REAL-TIME DATASTREAM

Via a DataStream Software Development Kit (SDK) you can easily program, and access information contained in the DataStream.

This allows for custom applications, increased third-party compatibility, modeling options and latency compensation.

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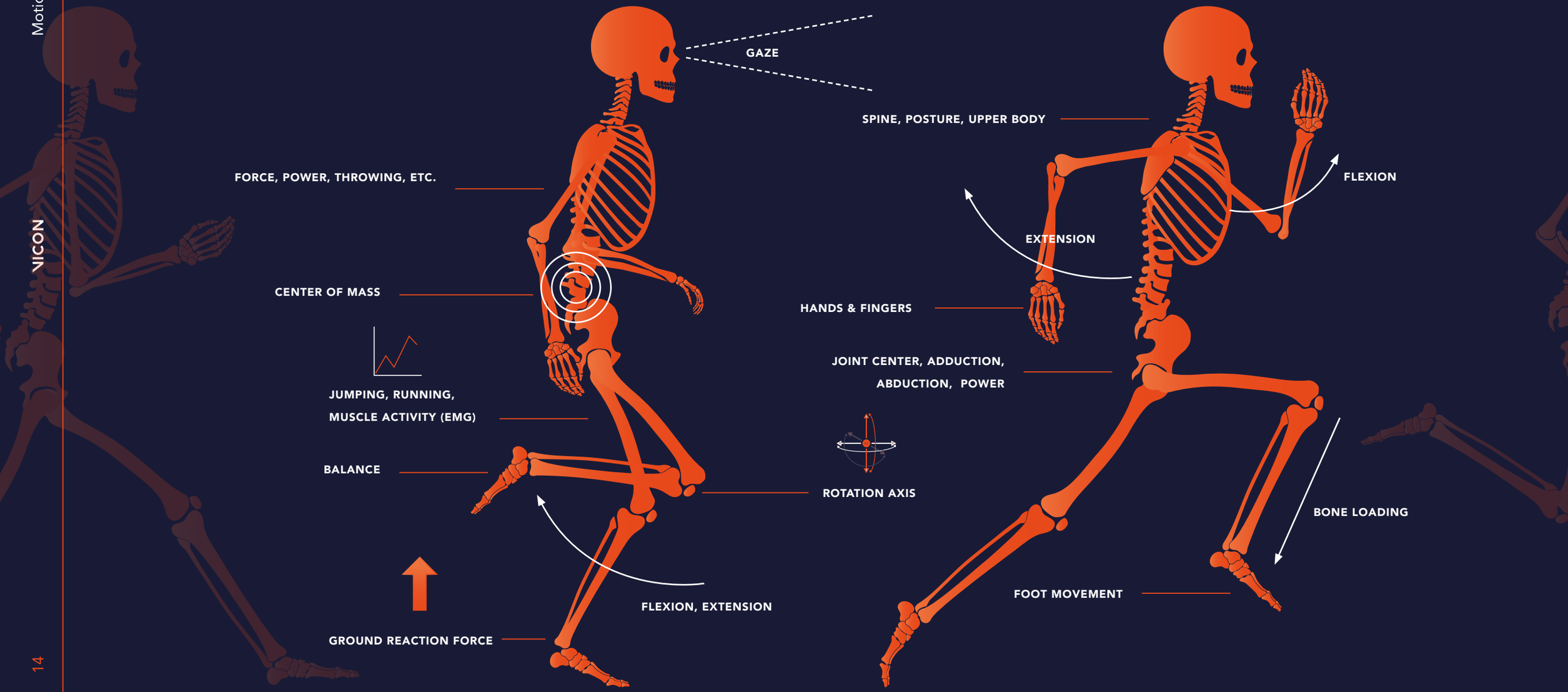
Life sciences motion capture model outputs



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Why use motion capture in life sciences?

Now you know what motion capture is in its many forms, and how it works – how do you decide if it's right for you?

Taking a look at some of the current users and applications of motion capture will give you a feel for how you might benefit from incorporating it into your work or research.

CLINICAL

WHO
- Biomechanists
- Clinicians
- Physicians & Surgeons
- Healthcare audiences as wide as Podiatrists & Ergonomists
- Physical Therapists/ Physiotherapists

WHY
- Gait or motion analysis of all kinds for medical purposes – diagnosis and rehabilitation
- Research
- Teaching

NEUROSCIENCE & MOTOR CONTROL

WHO
- Biomechanists
- Physicians & Surgeons
- Clinicians
- Physical Therapists/ Physiotherapists

WHY
- Treatment of conditions (e.g., cerebral palsy, arthritis, etc.)
- Rehabilitation
- Balance/reaching studies
- Research & teaching

ANIMAL SCIENCE

WHO
- Veterinarians
- Trainers
- Researchers
- Animal Physical Therapists/ Physiotherapists
- Evolutionary Biomechanists
- Equestrian Surgeons

WHY
- Veterinary medicine
- Performance improvement
- Injury rehabilitation
- Movement studies

SPORTS PERFORMANCE & BIOMECHANICS

WHO
- Sports Medicine Physicians
- Biomechanists
- Clinicians & Surgeons
- Physiotherapists, Strength & Conditioning Coaches, Coaches & Trainers of all kinds
- Exercise Scientists
- Sports such as running, swimming, team sports

WHY
- Technique and/or performance analysis
- Injury prevention
- Rehabilitation and return to play
- Research

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Who is using motion capture today?

If you feel like motion capture might be right for you, it's important to know that you're in good company.

By far the largest number of certified motion capture labs for clinical purposes use optical motion capture technology.

There are thousands of motion capture systems in life science installations all over the world and many thousands of research papers in which motion capture systems were used.

Current motion capture life science users include:

ADIDAS
AJAX FC
AMSTERDAM MEDICAL CENTER
AUSTRALIAN INSTITUTE OF SPORT
BASEL UNIVERSITY
GUY'S AND ST THOMAS' HOSPITAL
GILLETTE CHILDREN'S HOSPITAL
HIROSHIMA UNIVERSITY
HONG KONG POLYTECHNIC
HUMBOLDT UNIVERSITÄT ZU, BERLIN
JAPANESE INSTITUTE OF SPORT SCIENCE
KATHOLIEKE UNIVERSITY LEUVEN
KTH ROYAL INSTITUTE OF TECHNOLOGY
LI NING
LIVERPOOL JOHN MOORES UNIVERSITY
LOUGHBOROUGH UNIVERSITY
LUCILE PACKARD CHILDREN'S HOSPITAL
TELETON REHABILITATION CENTERS
NUFFIELD ORTHOPAEDIC CENTRE
PRETORIA UNIVERSITY
SHRINERS HOSPITALS
STANFORD HALL DMRC
TELETÓN AND REHABILITACIÓN INFANTIL
UNIVERSITY OF BRUSSELS
UNIVERSITY OF WESTERN AUSTRALIA

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Where do I get a motion capture system?

Many companies provide motion capture systems. When considering which one is right for you, there are some questions you can ask to ascertain if the technology and the fit is right:

1 What makes the company different?

2 Will the company work hand-in-hand with you as a partner and do they offer a consultative and tailored approach to meet your needs?

3 How long has the company been around and what's their heritage?

4 Do they make their own hardware and/or software? If so, what manufacturing and R&D expertise do they have?

5 What's the length of service of the team?

6 Where are they based – will I be able to reach someone if I need to and can we communicate effectively?

7 Will they provide an on-site demo of their system?

8 What partnerships and integrations does the company have?

9 Do they have an experienced and knowledgeable distributor in my country who speaks my language?

10 Are the distributors accredited and, if so, how?

11 Who are their customers – can I speak to any of them who are running applications similar to mine?

12 What support will I get at the installation?

13 Does the manufacturer come and install your system for you?

14 Does the team help you set up and calibrate your system?

15 Will the team train your team on how to use the software and help you start capturing data while they are on site at the install?

16 What's their post-install support offering and organization like?

17 What other resources – training, tutorials, etc. – do they offer customers after installation?

18 What happens if something goes wrong – what's their approach to fixing problems and what are their response times?

19 Is the platform relevant for my purpose and developed for my specific needs?

20 Can the company advise me about different capture methodologies – including optical, alongside inertial and/or markerless?

10
Start the conversation

QUESTIONS TO START THE CONVERSATION ABOUT MY MOTION CAPTURE SYSTEM

Am I capturing indoors or outdoors?

What's my budget? Is it in place already, or do I need help to submit a grant proposal?

Do I have a space for my lab? The degree to which it's ready will affect the installation time. If it's incomplete your provider can advise on how to structure the space.

What's the size of my lab and capture volume? The system will be tailored to your specific space. The number and type of cameras depends on the volume size and the activities that you want to capture.

How is my system being used? Systems are usually tailored to the application(s).

What kinds of movement will I typically be capturing?

Do I want to integrate additional technology such as inertial capture, force plates, EMG or reference video into the system? Can the manufacturer specify and source additional tools for me, or put me in touch with a distributor to do this?

How much detail do I want to capture from the subject? Factors such as whether you're capturing a full body or part, or whether you need feet and hands, can impact your setup. Will the manufacturer give you advice on all of these factors?

What modeling language or other programs do I want to use? It's important to make sure they're compatible, and that you have the licenses and/or plugins for software such as MATLAB or V3D.

What sort of subjects am I capturing? People, animals and objects all impact your system requirements differently, as do factors such as whether they have full mobility, their size, etc.

Am I capturing 1 or 35 subjects?

If your lab will be used for clinical gait, do you need software that is clinically validated and designed specifically for gait?

What outputs do I want to analyze? Does the software come with these models preconfigured or give an easy way to integrate models I have from another source?

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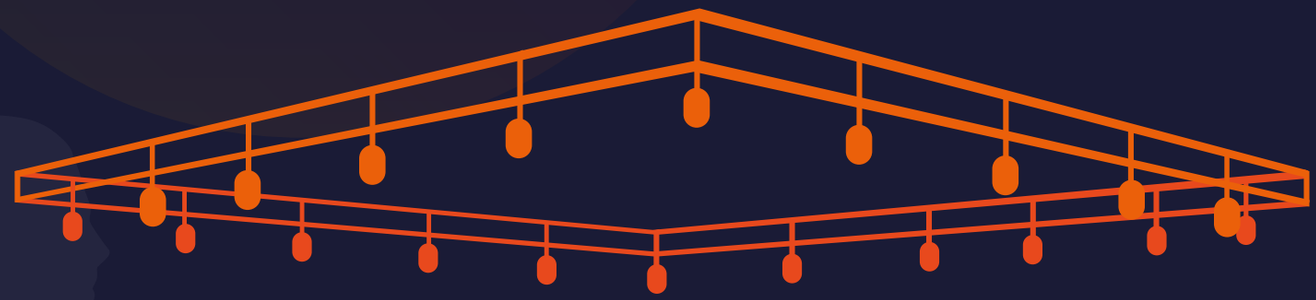
What will my lab look like?

While there's no such thing as a typical lab, you can work up a very effective visualization of what your ideal biomechanics lab will be before even speaking with a supplier.

Some manufacturers have tools to allow you to build your system on their websites – this will help you explore your options and get a feel for the process before you get in touch. Make sure your provider can then assist with lab design – offering advice and recommendations to suit your particular application – as choices can vary hugely depending on your individual facility and what you want to achieve.



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What else should I consider?

1. POWER

Do I have power sockets, or will I need a separate power supply? Will I need an uninterrupted power supply?

2. CEILINGS

What's my ceiling height and what's it made of? You will need a height of around 3m above the finished floor for human capture – although you can go lower for animal capture. Height should be 5m or more if you are conducting studies of stair climbing, golf swings, or similar activities. Non-reflective ceilings are advised.

3. TEMPERATURE

Will I want to regulate the temperature? Be aware that if vibrations from air conditioning units are severe, they may affect the walls and camera stability. Fans should be on a separate electrical circuit from the motion capture system.

4. WALLS

What are the walls like? What are they made of and how will I mount any trusses or cameras to the wall? Be careful of slamming doors and vibrations from adjoining rooms. Matt or satin paint is preferable, it doesn't matter what color.

5. INTERNET

Do I need an internet connection? Recommended for online help and receiving software and firmware updates conveniently.

6. WINDOWS

Does the room have windows? You don't need to create a blackout zone but it's useful to consider patient privacy, as well as to control the ambient lighting, like covering skylights, using backed, dark colored curtains or non-reflective blinds.

7. FLOOR

What's the floor made of – how will I ensure it's non-reflective? How stable is the floor – will I need to eliminate vibration if I'm in a hospital lab trying to measure gait?

8. SUBJECT PREPARATION

Where will my subjects get ready? Do I have a space for them to get changed and have the markers applied?

9. OBSTRUCTIONS

How clear is the room? Try to keep the room free from obstructions (such as columns, bookcases, storage cabinets, etc.) and reflective surfaces (mirrors, shiny doorknobs, metal plates around switches or wall power outlets, chrome kick plates, or railings).

10. OUTDOORS

If outdoors, how will I mount the cameras? Do I need a portable computer? How will I get power to the system?

11. CABLES

Do I need cables? Ensure the manufacturer provides them as part of your system.

12. THIRD-PARTY DEVICES

Which third-party devices do I want my system to integrate with? And are they analog or digital? Check if the manufacturer can provide the equipment to integrate either method.

13. MARKER SIZE

Do I want active or passive markers? If passive markers, what marker size do I need? It depends on proximity of markers to the camera, activity, subject size and biomechanical model. Check if the manufacturer can help or advise you.

14. DISPOSABLES

What disposables do I need? Additional or spare markers, double-sided tape or other means to affix markers?

15. STORAGE

Where will I store my markers, tape, calibration device, EMG electrodes, measuring tape, other lab supplies? Do I have a storage closet or cabinet available?

16. APPAREL

What clothing or apparel will my subjects need to wear for their comfort, safety or technique? Will the choice of motion capture technology dictate clothing requirements? Do other wearable devices need to be used at the same time? Check whether the manufacturer can help or advise you.

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Things to consider in the decision-making process

DISCOVERY
WEEKS

For support with obtaining a grant, larger or more complex projects, or some tenders, it could take weeks or months – see how quickly the vendor can move – will they react as quickly as you need them to?

DISCUSSION
1 DAY

If you have a clear idea of what your needs are, you can get a quote in a day.

DEMO
1 DAY

If you'd like a life sciences specialist to provide an on-site demonstration – or visit the company's offices – make sure the manufacturer can arrange that easily for you.

CONSIDERATION
1 – 3 DAYS

When you've made a decision, check how long full installation typically takes – it can be from one to three days.

And does it include in-depth training on running and automating the system, so all your users are adept in data capture, processing and refining their pipelines, and ready to start using the system before the installation team leave?

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What if I need more information?

If you need any more information about motion capture, Vicon, or how to use the relevant software and hardware then have a look at the useful links below:

WHAT IS MOTION CAPTURE?

https://www.vicon.com/whatis

MORE ABOUT MOTION CAPTURE FOR LIFE SCIENCES:

https://www.vicon.com/lifesciences

CUSTOMER CASE STUDIES:

https://www.vicon.com/resources/case-studies/

SYSTEM BUILDER TOOL:

https://www.vicon.com/vvt/

IMU ACADEMY:

https://imeasureu.com/academy/

YOUTUBE CHANNEL WITH VIDEO TUTORIALS:

https://www.youtube.com/c/ViconLifeSciences

MANUALS AND TECHNICAL DOCUMENTATION:

https://docs.vicon.com/

SOFTWARE DOWNLOADS LINK (FOR FREE POINT RELEASES)

https://www.vicon.com/downloads

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LEARN MORE ABOUT MARKERLESS CAPTURE:

https://contemplas.com/en/technologies/

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About Vicon in life sciences

In the 1980s Vicon's work in motion capture began with the life sciences. Over 35 years later we're still leading the field.

For practitioners in sports performance and biomechanics; gait analysis, neuroscience and motor control; or in animal science, Vicon offers the most advanced and customizable end-to-end motion capture solution(s) in the world.

The combination of precision-engineered optical and inertial hardware with powerful software enables users to capture in highly controlled lab settings or out in the field without ever leaving the Vicon ecosystem.

We understand that providing powerful tools and incredible data fidelity isn't enough, however. Our clients are constantly pushing boundaries, so we give them tools with the flexibility to match that spirit of innovation. Whether it means making sure that Vicon technology works with other instruments in your lab, offering an open source SDK, integrating with third-party software or just giving you the most adaptable tools possible, we make sure Vicon systems fit with your application, not the other way around.

For more information visit:
https://www.vicon.com

In 2017, Vicon acquired New Zealand based wearables company, IMeasureU to accelerate its Inertial Measurement Unit (IMU) product offering to enable researchers, coaches and elite athletes to benefit from data-driven performance insights.

IMeasureU Step is a wearable, multi-limb, movement measurement platform that provides actionable data in the lab and on the field. Using world class sensors, software and science combine to enable precise insights that inform movement and rehabilitation optimization.

For more information visit:
https://imeasureu.com

The year 2021 marked another milestone in Vicon's history – the acquisition of CONTEMPLAS, which brought video-based motion analysis to the Vicon ecosystem.

CONTEMPLAS is one of the leading providers in the field of video-based movement analysis, developing and distributing worldwide software solutions for general motion analysis. CONTEMPLAS' TEMPLO® software can record and track motion across a range of activities including walking, running, sprinting and swimming among many others, whether in training or in competition.

CONTEMPLAS' TEMPLO® motion analysis software measures a wide variety of applications and provides 2D and 3D insights using the latest video technology and sophisticated image processing.

For more information visit:
https://contemplas.com

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