OPTRONICS

UNDERSTANDING THE ESSENTIALS

NEXVISION
OPTRONIC DESIGN

Part 1 : Vision, color and the electromagnetic spectrum
Part 2 : Training, processing and analysis of a digital image
Part 3 : Architecture
Part 4 : Your project

Are you a Director of Innovation and need to bring innovation to your products?

This white book has been conceived as a practical guide aiming to inspire, but above all, to allow you to have an understanding of the basic concepts of optronic systems so as to better comprehend the key points in developing a vision system.

With the evolution in technology (processing power, miniaturization of components etc.) it is now possible to achieve more elaborate applications from vision systems: detection, tracking, recognition, measurement of the environment etc.

This opens a whole range of unprecedented possibilities in many fields: aeronautics, space, defense & security, industry, transport (especially in the case of autonomous vehicles).

I hope this booklet will be a source of inspiration and will assist you in the conception of new applications for your projects in vision.

Vincent CARRIER
CEO NEXVISION

Part 1 : Vision, color and the electromagnetic spectrum

Why do we see an object ?

As you well know, humans see in color, especially during the day.

If you see an object, it is only because it is illuminated by a light source and its color is detached from that of its background, i.e. the environment in which it is located. The boundaries of objects are simply the differences in their colors and contrasts, and thus, in its setting, humans are able to distinguish several forms, in order to analyse and interpret what is happening.

People see what is reflected from the light, and so, the color of a surface depends on how it is illuminated and in our position as an observer.

If you look at objects or people in a normally-lit room, you see the result of the reflection of light on these objects.

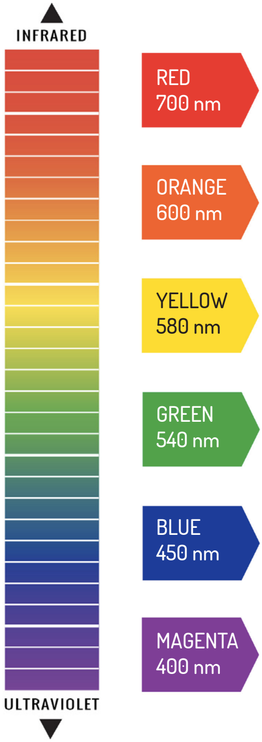
What must be kept in mind at this stage, is that all matter on the planet (human skin, leaves, the sea, metal, stone etc.) will react differently when it is illuminated. Light can be reflected on all matter; it can be completely absorbed, or partially-absorbed and partially-reflected, and can be seen as different colors. We will look at this in more detail later on.

Where does color come from ?

The white, natural light coming from the sun is actually composed of different colors. You may remember this experiment where a luminous ray is passed through a prism and the colors of the rainbow appear.
This simply shows how the sun's «white» light is composed of several colors. Each color is an electromagnetic wave with a well-defined wavelength. Depending on the size of the wavelength, it will not propagate at the same speed through the prism; and in having a specific shape, it will deflect the wavelength's output.

Furthermore, the part that humans can see with their eyes, known as the «visible spectrum», is only a very small part of the complete electromagnetic spectrum, however, we will come back to this later.
We can see these colors because our eye is sensitive only to rays whose wavelength is roughly between 0.38 and 0.75 millionths of a meter, in other words, between 380nm (violet) and 750nm (red).
Between these 2 values, we find the different shades of the colors of the rainbow.

According to the value of this wavelength, we perceive these rays as a light of a certain color. Thus, if we look at a lamp that emits light with a wavelength 0.4 μm (400nm), we will see it as violet. If the lamp emits a shorter wavelength (in the ultraviolet), we will not see anything, because it is below the threshold of the eye's sensitivity. This is the case for wavelengths greater than 750nm.



Primary, secondary and tertiary colors

Among these colors, 3 are primary colors: Red, Green and Blue.

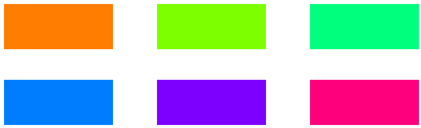
We call these 3 colours primary colors, because it is possible to create all the colors of the rainbow from them.

Primary colors are mixed to get secondary colors. For example, when red and green are mixed, we get yellow (this is called additive synthesis).

Secondary colors: cyan, magenta, yellow.

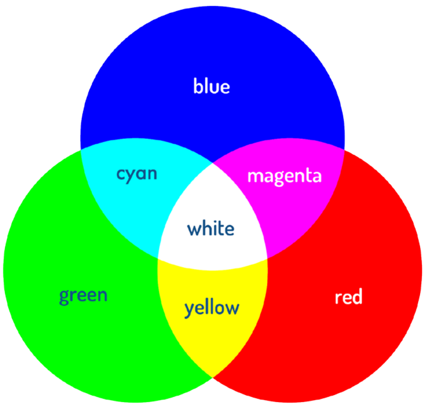
Finally, tertiary colors can be obtained by mixing a primary color and a secondary color.

Tertiary colors: orange, chartreuse, spring green, azure, violet, rose (RGB).



<u>Please note</u> :
As for the colors of the rainbow, if we add the primary colors, red, green and blue together, it will create white.

Black is the absence of color.



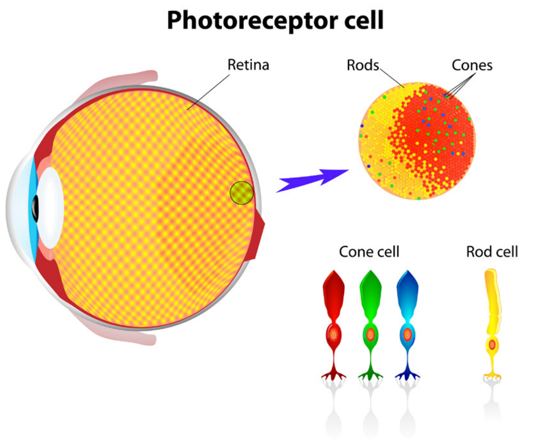
Eye function and the vision mechanism

At this point, it is important to understand the connection between the colors that make up the white light of the sun and the human eye.
We have seen previously that the visible spectrum extends roughly 380 to 750nm, which is an extremely small wavelength.
But then why would the human eye only be sensitive in this frequency band?
In fact, inside the human eye, there are cones and rods.

These rods are cells that are sensitive to light intensity: they translate for our brain the degree of light radiance.

However, they cannot differentiate two equally bright colors. In addition, rods are much more sensitive than cones. In fact, when we are in a weakly-lit environment, we have difficulty distinguishing colors and thus, objects appear grayish; in this situation, the light is sufficient to stimulate the rods, but not the cones. At night, it is the rods that allow us to see.

Cones are cells that react to color. They allow the differentiation between two shades. There are ten times less cones than rods. Three types of cones have been discovered, each being sensitive to a certain range of wavelength: the «S» cones are quite sensitive to blues, the «M» to greens and the «L» to reds.
Humans are therefore equipped with cells sensitive to the three primary colors: red, green and blue. It is also in relation to our reference as being human beings, that we decreed that these three colors were primary colors.
And when we speak of a «visible» light spectrum, we are talking about a visible spectrum in relation to human capabilities. Other living species may have a «visible» spectrum different from ours, and have cells that are sensitive to other wavelengths.



In summary, the light that comes from an object that we observe (emitted or diffused light) will penetrate our eye through the pupil (responsible for regulating the entering luminous flux), crossing the lens then the eyeball, and will eventually stimulate the nerve cells lining the retina, in the back of the eye, that is, the cones and rods. Each type of cone is more or less stimulated according to its type (S, M or L) along with the composition of the light received. This is the set of signals that are interpreted by the brain to match a color.

And so, yellow light will stimulate cones M and L (which despite their sensitivity in red and green, are sensitive to wavelengths in yellow), but not S (sensitive to blues). The information «green» + «red» will be translated as «yellow».

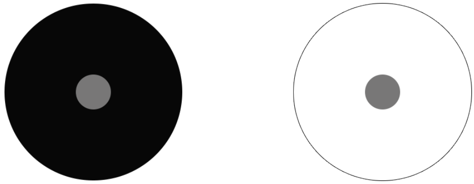
Things to know (1):
About 80% of cones line the central area of the retina, or fovea. This area corresponds to where the center of the image is formed. At night, in the dim lighting of the stars and a quarter-moon, we cannot distinguish objects that are right in front of us. In fact, the fovea do not contain rods (100% of the rods are placed on the retina), and therefore do not react to low light.

In order for our brain to «understand» what is in front of us, we need to move our eyes, or «sweep» the scene so that the rods, present around the fovea, «see» what interests us. This method is well known in the military.

Things to know (2):
It has been previously indicated that the environment has a strong influence on our perception of colors.

To demonstrate this, here is just one example of contrasts in brightness.
Our eye adapts to the average light intensity of a particular area. In a very bright environment, our pupil closes to «regulate» the flow of light received. In the dark, the pupil opens wider. Immediate consequence: the same color will be perceived as darker on a light background than it is on a dark background.

In the example below: the gray dot in the center appears lighter to the left than to the right when in fact, it is exactly the same color.



This also applies to contrasts of saturation or tones.

So, why do we see objects in color ?

In order to do this, we must first understand a few concepts...

A. Behaviour of different matter when lit-up by a light beam

All matter (living, material etc.) reacts to light.
For example, if a ray of light hits an object, it can:

1) Reflect part of this light
The light hitting the object bounces off the surface towards our eye. Most things around us behave like this: a table, a piece of clothing, fruit, as well as the moon or any planet seen from the Earth.
The ratio of reflected energy to incidental energy is called reflectance.

2) Absorbing a part of these light rays
The ratio of absorbed energy to incident energy is called absorbance.

3) Transmitting part of these light rays

Is partial but more or less faithful. The received light passes through the object's matter, is filtered, and continues its way towards our eye. A colored plastic filter, a slide, spectacles and sun-glass lenses are a few examples.

The ratio of transmitted energy to incident energy is called transmittance.

4) Re-emitting part of the light absorbed in the form of far-infrared radiation

In a steady system (the absorbed radiation and the temperature of the material are constant). The ratio of the energy emitted to the energy absorbed is called the emissivity coefficient.

And of course, some materials lit by certain rays can do all of this at once.

And so, each material, has its own properties and therefore reacts differently according to the wavelength of the light it receives.

Note :

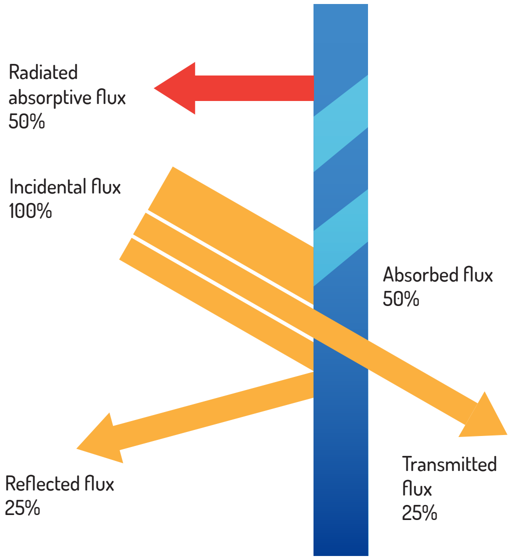
The object itself may emit light: this is the case of a light bulb, the flame of a candle, the sun, a LED etc.

B. Application in the case of light

We have seen how the sun's white light is composed of different wavelengths which correspond to different colors.

What we need to understand is quite simple

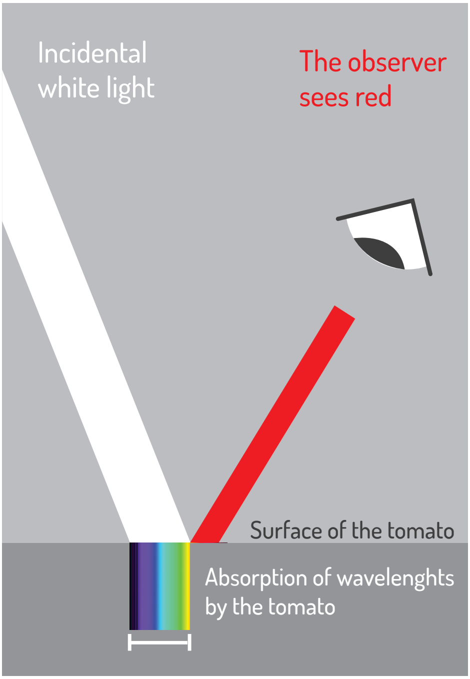
...



When we illuminate an object with a white light, the object will interact with this light, which, as you recall, is composed of several wavelengths.

As seen in the previous paragraph, some wavelengths can be absorbed, others reflected, transmitted or re-emitted, depending on the properties of the matter.

Let's take the case, for example, of a tomato. If we illuminate it with white light, the properties of the tomato will make it absorb the blue and green rays (that is, the part of the spectrum from purple to orange), which then reflect the red rays that reach our eye. This is why humans see a red tomato during the day.



If you put the tomato in the dark and light it with a yellow spot light or magenta, the fruit will still look as red. And so, yellow light is formed from red and green, and magenta light from red and blue. The tomato absorbs everything except red, so our eye receives the red wave by reflection: for a human, its appearance has not changed.

If, on the other hand, we now light it up with a green or blue light (which do not contain a red component), the tomato will look black to us because it will have absorbed all the rays and nothing will have been reflected towards our eye.

We gave an example using a ray of light, however, this functions in exactly same way as for any type of beam on the full spectrum. Objects can also emit or reflect wavelengths that are invisible to us. It's just a matter of interaction between the matter and the wavelength of the incidental ray.

We will also see that for some applications, it is useful to «illuminate» by infrared, i.e. an infrared transmitter will illuminate a setting (nothing is seen to the naked eye) and use a sensitive infrared receiver, which will then recover the reflected rays, in the exact same way as the human eye which recovers the rays of light reflected by the object being looked at.

Things to know :
For the reflectance of a surface, the term, Albedo is also used, which indicates the reflectivity of a surface (its reflection coefficient). It is a dimensionless size between 0 (no reflection, everything is absorbed) and 1 (total reflection).

What about the rest of the electromagnetic spectrum ?

The visible part of the electromagnetic spectrum (by humans), which we saw earlier, is actually only a minute part of the full spectrum.

From either side of the visible spectrum there are different bands of frequency containing different properties and uses. We do not see these waves, but we can feel a few of them:

By going towards higher frequencies (thus shorter wavelengths), we will first find the Ultra-violet rays (UV-a and UV-b produced by the sun, we can't see them but they make us tan and can be very dangerous for the skin and eyes!). Next, we find X rays that serve especially in the medical field and finally, Gamma rays.

As we move towards lower frequencies, Infra-red is found initially, which can be sub-divided into VNIR / SWIR bands for near infrared and MWIR / LWIR bands which correspond to thermal. We can feel radiation in the form of heat. Next, we find the TeraHertz band which links the field of photonics with radio waves. The THz is used, for example, in airport doorway-detectors (to detect weapons). Next, there are microwaves which have numerous applications, including radar. This then brings us to radio and TV waves, used for mobile telephony, radio or TV.

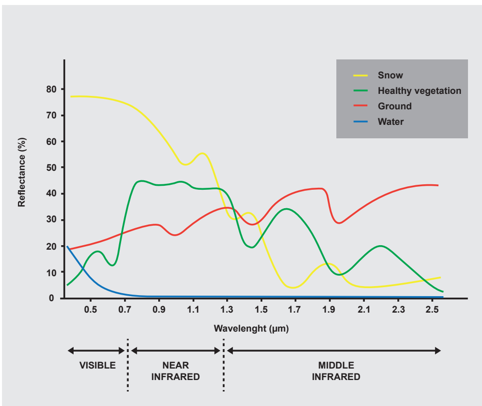
All these waves are not visible to humans, but they are «visible» by receivers or sensors.

For example, there are image sensors in the visible spectrum (that is, in sensors that are used to make cameras), however, there are also image sensors in UV, infrared, Thz etc. which serve in manufacturing cameras for which the result must be adapted for humans to be able to visualize and interpret these images.

Spectral signature of differing matter

Depending on the issue needing to be solved with a vision system, we will start by studying the spectral signature of different matter in order to find a frequency band in which it reacts and then building the complete system permitting it to be «seen» so as to detect the item in the desired frequency band.

For example, here is a graph illustrating the **spectral signatures of the predominant natural surfaces**:



What this graph teaches us:

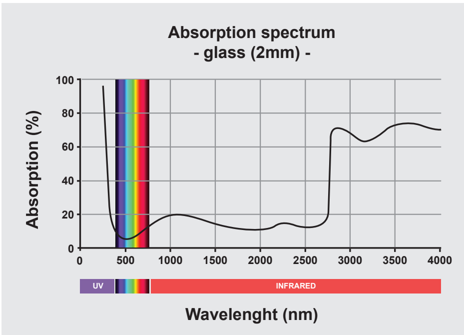
- That snow has a strong reflectance in the visible spectrum but is very weak in the mid-infrared;
- That vegetation reflects green (approx.530nm in wavelength) but also has a strong reflectance in the near-infrared; and so, if we illuminate a leaf in the near infrared, it will appear white on a screen;
- That water reflects part of the visible light but completely absorbs the infrared; so if we illuminate a setting with an infrared source, the water will appear black on a screen.

Note : each type of plant or tree possesses a unique spectral signature which depends on its growth, as well as its environmental conditions and constraints (humidity, temperature, etc.)

In the case of glass:

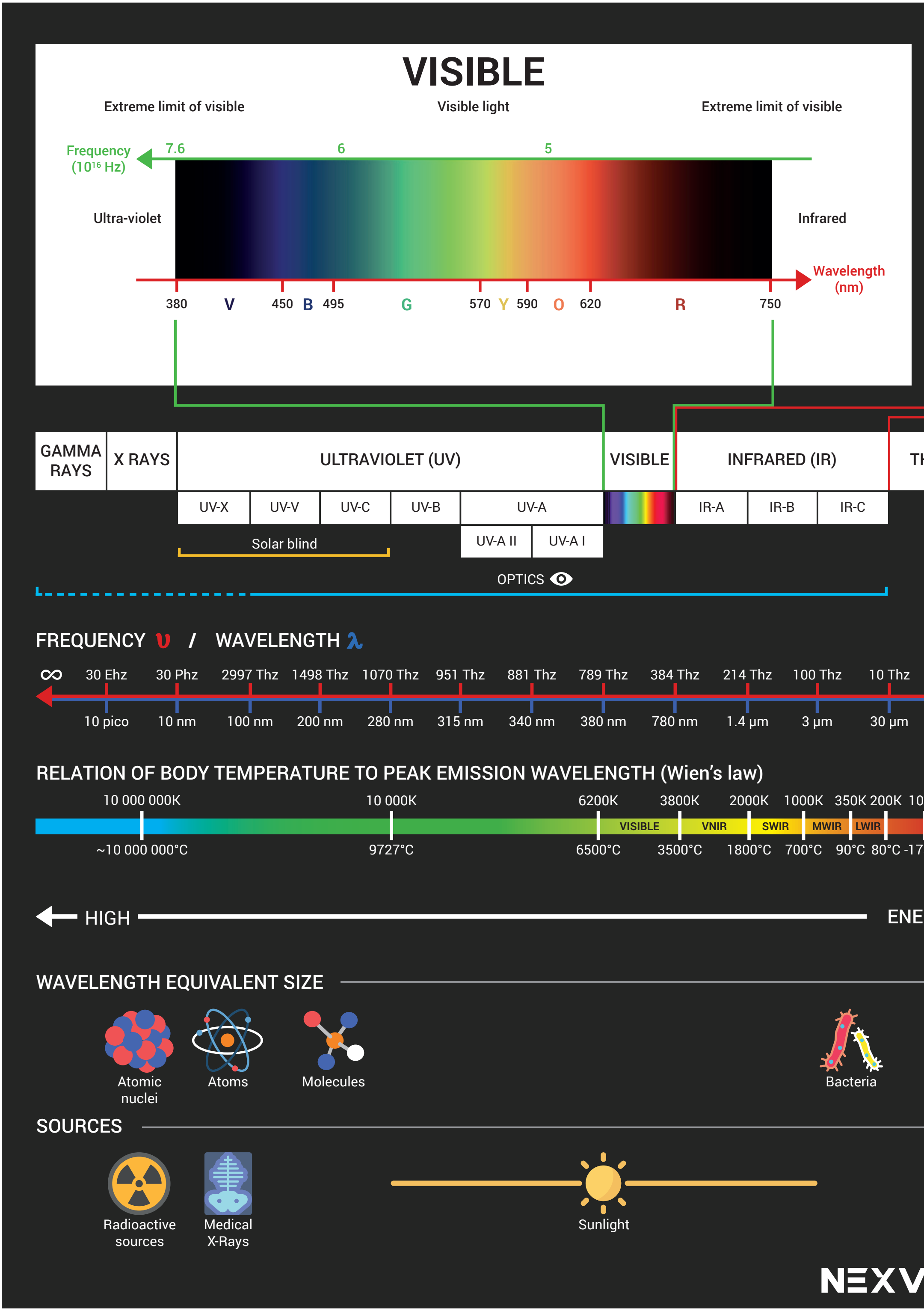
Glass has the characteristic of having a high transmittance for solar radiation (visible light and near-infrared) but a low transmittance for far-infrared radiation; in other words, glass blocks far-infrared light rays by absorbing them. Thus, if you see a person with glasses in the far-infrared (thermal), you will see color gradients in the areas of their body that give off heat whilst their glasses will be black.

Glass is therefore ideal for creating a greenhouse effect: it allows the sun's rays to pass through and trap infrared rays re-emitted by other matter. In this diagram, we see how glass absorbs a part of the UV and far-infrared rays whilst letting the visible spectrum waves pass in the near-infrared.

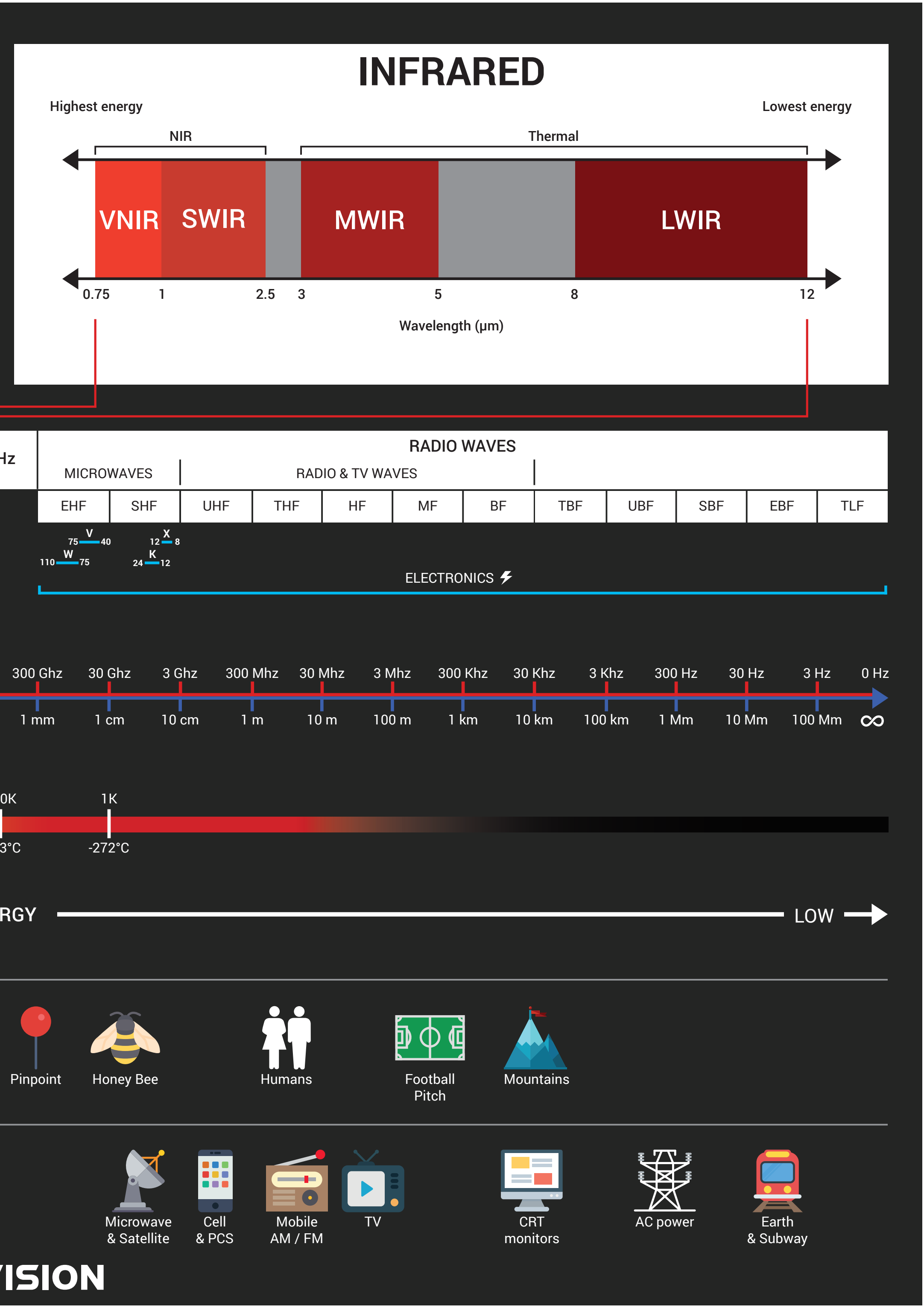


In the military field, optronic systems using different frequency bands are used according to the operating conditions, in particular for detection, recognition and identification. On the other hand, camouflage techniques, whose goal it is to delay images for a maximum detection time, have benefited from enormous technological progress, whether it be in the dissimulation of the individual fighter, of vehicles or the reduction of the electromagnetic signature forces (e.g. infrared signature).

There is intense competition in this domain with more and more powerful means of detection (radar, infrared, thermal) with technologies that reduce the electromagnetic signatures of people and equipment. And thus, the eternal duel between the sword and the shield continues...



VISIBLE
Extreme limit of visible
Visible light
Extreme limit of visible
Frequency (10¹⁶ Hz)
7.6
6
5
Ultra-violet
Infrared
Wavelength (nm)
380
V
450
B
495
G
570
Y
590
O
620
R
750
GAMMA RAYS
X RAYS
ULTRAVIOLET (UV)
VISIBLE
INFRARED (IR)
TH
UV-X
UV-V
UV-C
UV-B
UV-A
IR-A
IR-B
IR-C
UV-A II
UV-A I
Solar blind
OPTICS
FREQUENCY υ / WAVELENGTH λ
∞
30 Ehz
30 Phz
2997 Thz
1498 Thz
1070 Thz
951 Thz
881 Thz
789 Thz
384 Thz
214 Thz
100 Thz
10 Thz
10 pico
10 nm
100 nm
200 nm
280 nm
315 nm
340 nm
380 nm
780 nm
1.4 µm
3 µm
30 µm
RELATION OF BODY TEMPERATURE TO PEAK EMISSION WAVELENGTH (Wien's law)
10 000 000K
10 000K
6200K
3800K
2000K
1000K
350K
200K
10
VISIBLE
VNIR
SWIR
MWIR
LWIR
~10 000 000°C
9727°C
6500°C
3500°C
1800°C
700°C
90°C
80°C
-17
HIGH
ENE
WAVELENGTH EQUIVALENT SIZE
Atomic nuclei
Atoms
Molecules
Bacteria
SOURCES
Radioactive sources
Medical X-Rays
Sunlight
NEXV



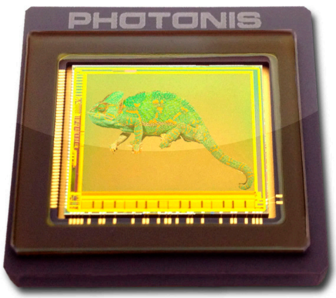
INFRARED
Highest energy
Lowest energy
NIR
Thermal
VNIR
SWIR
MWIR
LWIR
0.75
1
2.5
3
5
8
12
Wavelength (µm)
Hz
RADIO WAVES
MICROWAVES
RADIO & TV WAVES
EHF
SHF
UHF
THF
HF
MF
BF
TBF
UBF
SBF
EBF
TLF
V 75 40
W 110 75
X 12 8
K 24 12
ELECTRONICS
300 Ghz
30 Ghz
3 Ghz
300 Mhz
30 Mhz
3 Mhz
300 Khz
30 Khz
3 Khz
300 Hz
30 Hz
3 Hz
0 Hz
1 mm
1 cm
10 cm
1 m
10 m
100 m
1 km
10 km
100 km
1 Mm
10 Mm
100 Mm
0K
1K
3°C
-272°C
RGY
LOW
Pinpoint
Honey Bee
Humans
Football Pitch
Mountains
Microwave & Satellite
Cell & PCS
Mobile AM / FM
TV
CRT monitors
AC power
Earth & Subway
ISION

Part 2 : Building, processing and analysis of a digital image

Image sensor

What is an image sensor ? What is it for ?

An image sensor is an electronic component that aims to **capture** and **digitize** images.



How does it work ?

To understand how an image sensor works, you first need to understand two things:

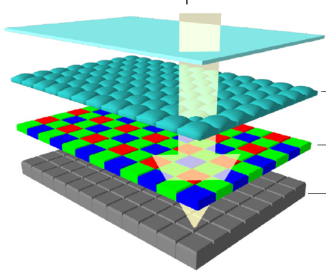
1. Light is composed of photons, i.e. small particles of energy created by a light source (e.g. sun, light bulb etc.).
2. It is possible to «convert» photons into electrons, which is called the photoelectric effect. In physics, the photoelectric effect (EPE) refers to the emission of electrons by a matter, usually metallic, when it is exposed to light or electromagnetic radiation of sufficiently high frequency, depending on the matter.

More specifically, an image sensor transforms light energy into electrical energy. It is composed of photosensitive cells, called photodiodes.

If a photon containing enough energy «hits» the photocathode, it will release an electron that will generate an analog electrical signal. The analog / digital converter will then allow this information to be digitized.

These photocathodes are arranged on the surface of the sensor in such a way that they form a matrix of pixels. This matrix gives us the definition of the sensor (for example an HD sensor comprises 1920 pixels wide x 1080 pixels high).

In addition, the sensor is equipped with a filter (often Infrared), microlenses (which can channel the light to the photosites) and a Bayer filter (which allows it to recover the color at the pixel level).



What are the characteristics of an image sensor ?

> Frequency band: UV / Visible / Night / SWIR / THERMAL / THz
> Manufacturing Technology: CCD / CMOS / EBCMOS
> Physical dimensions: length x width
> Resolution: image size in pixels (width x height) and pixel size
> Sensitivity: ability to capture high-quality images according to luminosity
> fps *: frame / second = the number of frames per second that the sensor is able to capture
> Type: Rolling Shutter / Global shutter, i.e. the way of exposing photosensitive cells [rolling shutter: display of lines one by one > spaces between the lines / saves transistor output and capa for each pixel, therefore much cheaper (easier to manufacture) / global shutter: everything displayed at the moment its being read]

***fps (frames / second) : kézako ?**

A video is in fact, a succession of still images. By putting them end to end, we end up seeing a moving scene.

It takes about 25 frames per second for humans to see a video in a fairly fluid way. Anything under that is seen as jerky. Going beyond 25 frames / second can be very useful for slow motion. Remember those ads where we see a gently falling drop of water and then a playful multitude of mini drops? This is possible thanks to many images being captured in a very short space of time.

In other words, if you need to capture a scene in which objects move very fast (ex: Formula 1) and want to see, for example, exactly which 2 cars cross the finish line first (in case they pass the line at the same time),an image sensor that is capable of capturing a very large number of frames per second (for example, 60 to 100 frames per second) will need to be used so as to be able to scroll through the images frame by frame to get an accurate result.

Once the light is transformed into electrical energy, it is necessary to be able to:

- Reconstruct images (pre-processing & image processing)

Then, be able to either :

- Store them (record video) ;
- Analyze them (extract information from the images, this being from the observed scene)
- Transmit them (e.g. to a command center)
- Display them (for example on a display [micro-screen, computer screen etc.])
- Or all at the same time!

What is image processing ?

Reconstructing images as closely as possible (whatever the environmental conditions may be).

In the blue section of the opposite table, a whole range of algorithms allowing the re-creation of images from the data captured by the image sensor can be seen.

In order to do this, very complex operations must be performed in real time, so as to deal with:

- The sensors' raw information
- Corrections and improvements to optic performance and the system (aberrations, distortion, stabilization etc.)
- Pre-processing corrections (auto-exposure, dead pixel correction etc.)
- Improvements such as HDR, contrast enhancement, vibration correction etc.

What is image analysis ?

Extracting information from the observed setting so as to decide on and launch different measures.

In the yellow part of the opposite table, different algorithms which can analyze an image's pixels so as to extract information can be seen.

This can involve algorithms:

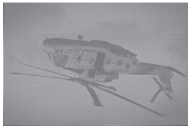
- Of detection
- Recognition (letter, shape, pattern etc.)
- Tracking
- Measurement of the environment
- Reconstruction of a 3D scene etc.

As you can appreciate, a vision system is not just a simple camcorder that serves only to film a vacation, but is a powerful system composed of, not only an image capture system in different frequency bands, but of an intelligence (analytical) whose applications are broad and applicable in many areas. It also serves in increasing human capacity by having the ability to see what we normally cannot, whilst dealing at a very high frequency which we are also unable to do.

IMAGE PROCESSING & ANALYSIS

Functions and algorithms to reconstruct, process and analyse images from sensors





ANALYSIS RESULTS
- Type : Helicopter
- Color : Yellow
- Speed : x pixels/s
- ...

IMAGE CAPTURE

MULTISPECTRAL IMAGE SENSORS
- > UV
- > Visible
- > Night vision
- > SWIR
- > LWIR / Thermal
- > TeraHertz

OPTICAL

OPTICAL ENHANCEMENT & CORRECTIONS
- > Super resolution
- > Aberration corrections
- > Chromatic aberrations
- > Relative illumination
- > Distorsion correction
- > Fisheye correction

DECONVOLUTION
- > Image reconstitution
- > Recursive algorithms
- > Denoising
- > Myopic deconvolution
- > Lens defocused
- > Multi channels deconvolution

STABILIZATION
- > Close control loop
- > Piezo actuator
- > Motion compensation
- > Viewer pointed

PRE PROCESSING

IMAGE SENSOR PRE PROCESSING
- > CFA Bayer to RGB
- > Auto exposure
- > Multi resolution
- > Color matrix correction
- > Auto white balance
- > Gamma & YUV/HSI color conversion
- > Dead pixel correction
- > Non uniformity correction (FPN)
- > DSNU & PRNU
- > Anti flickering
- > Lab color space conversion
- > 2D Image scaling
- > 3D lookup table color correction
- > ACES color space management

ENHANCEMENT

DYNAMIC RANGE : HDR & NOISE FILTERING
- > High Dynamic Range
- > Dynamic local tone mapping
- > 3D noise filter
- > Contrasts & edges enhancement
- > Spatial filters

VIBRATION CORRECTION

ANALYSIS

DETECTION / RECOGNITION

Methods
- > Feature extraction
- > Pattern matching
- > Texture recognition
- > Optical Character Recognition
- > Smart line detection (rail, lane, path, horizon)
- > Multispectral band object recognition
- > Content based image retrieval

Applications
- > Suspicious stationary object detection
- > Motion detection
- > Number plate recognition
- > Traffic accident detection
- > Streetcar line detection
- > Fire detection
- > Pedestrian counting
- > Human body detection
- > Gesture recognition

TRACKING
- > Online tracking
- > Specialized trackers
- > Autonomous tracking initialization

MACHINE LEARNING
- > Shallow learning
- > Deep learning
- > Neural networks

ENVIRONMENT MEASUREMENT
- > Augmented reality
- > SLAM
- > 3D scene reconstruction
- > Localisation / positioning
- > Advanced Driver Assistance System
- > Ground speed estimate
- > Unified scene alignment
- > Depth map
- > Sensors fusion
- > Barcode / QR Code reading
- > 1D, 2D, 3D measurement

Part 3 : Design

Computing power & interoperability

Now that the main concepts have been mastered, we know that to implement a powerful vision system, especially if it's to be embedded, it is necessary to use the latest technologies in order to benefit from adaptive computing powers and evolutive systems.

For example, if the image sensor is a 2M pixel sensor, running at 25 frames / second, it will have to process 2 million pixels x 25, or 50 million pixels / second (this is approximate and is just to give an idea of the computing capacity required).

The goal is to get the system working in real-time and interacting with its environment.
At Nexvision, we don't hesitate to implement the latest technologies straight out of the lab, be it in terms of image sensors, graphic processors or any other type of component.

As a matter of fact, we are one of the few companies in Europe who were the early adopters of Nvidia GPUs, and have been working very closely with Photonis to develop their EBCMOS sensors for night vision.

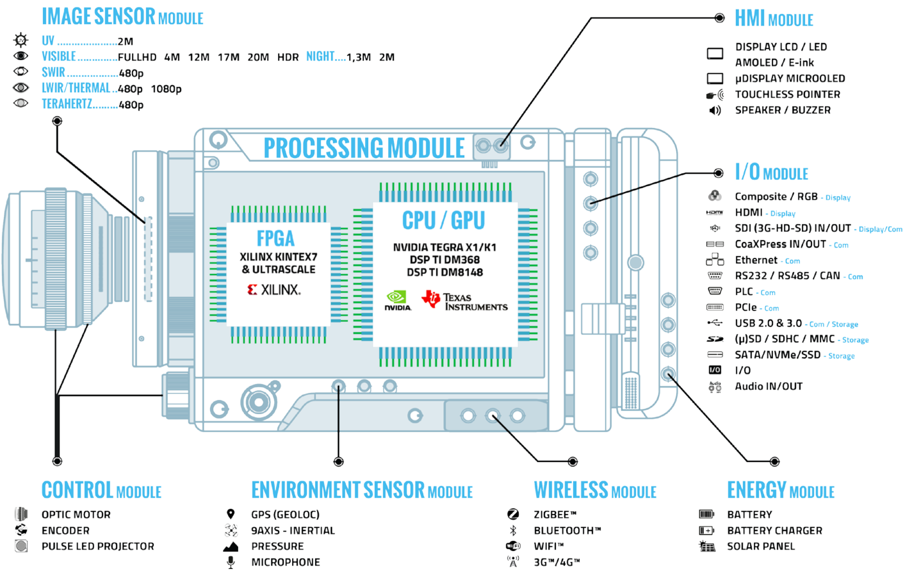
We not only develop complete systems, beginning with image sensors, but also include the development of an entire tailor-made system that goes with it; this being, the hardware as well as software, including the processing and / or image analysis algorithms.

In most cases, we create embedded electronic designs where CPU, GPU and FPGA constitute the heart of the system and the computing power.

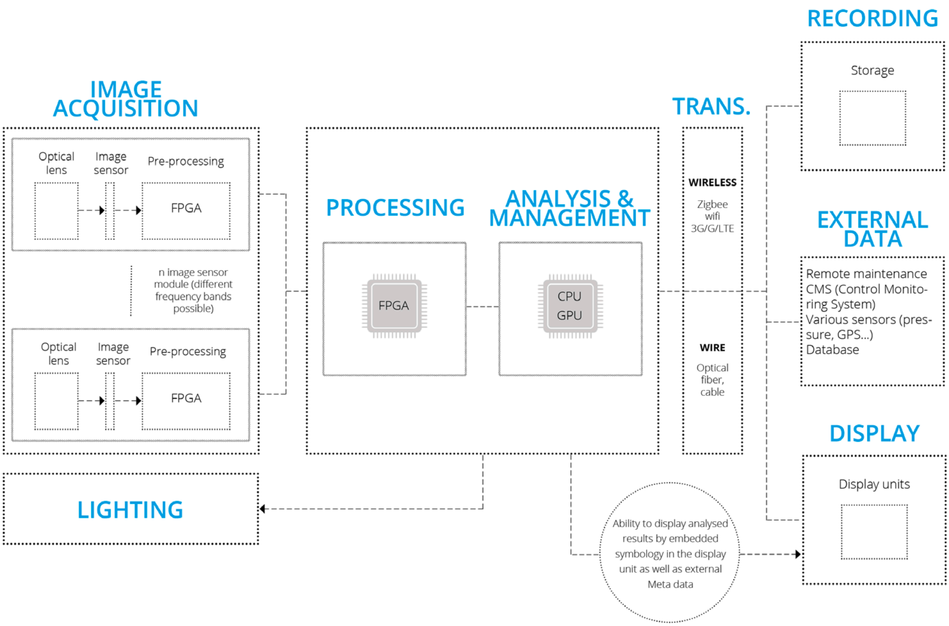
Note:
Depending on the design, there may be:

- Multiple parallel image sensors (with the same frequency band or different bands to capture different spectra)
- Remote heads with embedded image pre-processing systems
- Other types of sensors (e.g. radar, lidar) that complement the system and its interface to carry out the fusion of sensors, making the overall system even more precise.

ex : Camera 1 design



ex : n camera design



CPU - Central Processing Unit

The Conductor !

Runs the operating system (OS) and performs algorithmic processing at a high level. Makes decisions, manages the human-machine interface, and the application in relation to a given profession.

GPU - Graphical Processing Unit

The analyst !

Does some image processing but mostly image analysis e.g.: can deal with point clouds => the GPU takes these characteristic points and does an image analysis to extract relevant information.
On the technical side, it does floating calculations.

FPGA - Field-Programmable Gate Array

FPGA is row computing power !

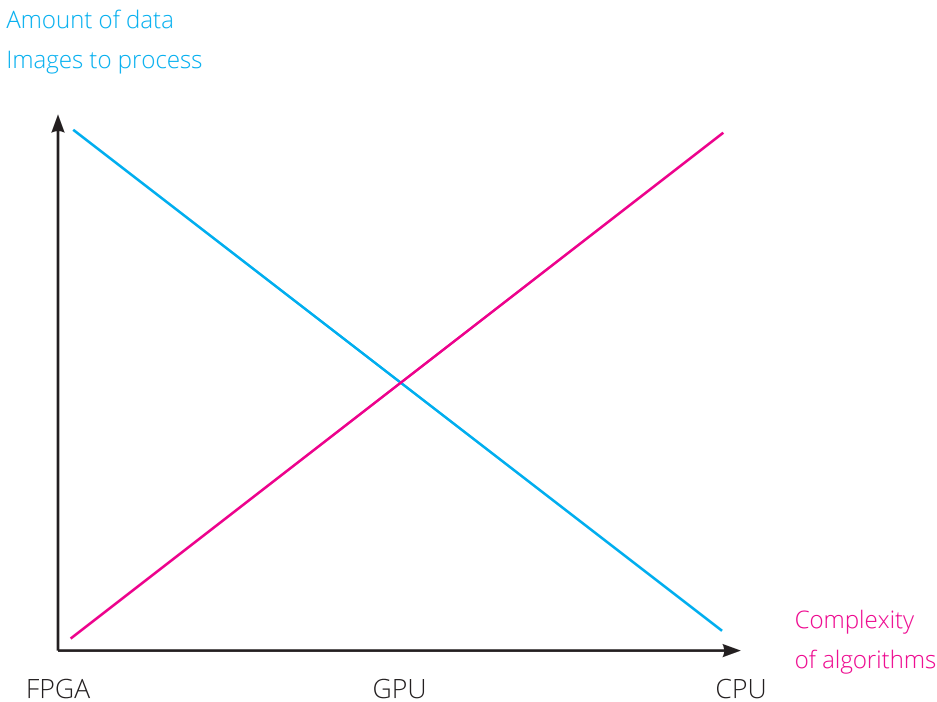
It takes raw images and performs pre-processing by improving and extracting their characteristic points. It is a true performer that does «simple» calculations on a large-scale.
On the technical side, it does full calculations.

HardWare: sequential logic in HW: strong parallelized data processor with access to defined memory (non-random) => implementation of algorithms in the form of a sequencer HW: not coming from the software.

<table>
<tr><th></th><th></th><th>Latency</th></tr>
<tr><td>CPU / GPU</td><td>Intelligent parallel computing</td><td rowspan="2">FPGA latency < CPU latency</td></tr>
<tr><td>FPGA</td><td>- Enormous parallel computing with no decision-making
- No random access to memory
- No connection (If - Then - Else)
- Simple pre-treatment algorithms (no choice list e.g. if this then that)</td></tr>
</table>

Things to know

Coding an algorithm on FPGA takes on average 20 times longer than for a CPU / GPU (that is, 20 times more difficult = more expensive).
The first design selection starts with a CPU / GPU and if there's not enough computing power, one or more FPGAs are added.



Part 4 : Your project

Do you have a vision project ?

Things to ask yourself:

For every vision project, and depending on the problem to be solved, it is necessary to take into account:

- What needs to be seen, detected, recognized, identified
- How will the system be used? (Fixed, portable - by hand, on the head)
- The type of setting, the environment in which the scene is taking place: water, air, disturbed air (fog, snow, sand, smoke etc.), day or night.
- The properties of the matter of the target (electromagnetic signature)
- Are there specific conditions: electromagnetic disturbances, temperature (min / max, variations etc.), ambient lighting (variation, brightness, frequency of lightning etc.) vibrations.
- Distance between the target and the object / media to scan
- Standards to respect

What to choose:

- The frequency band
- The sensor adapted to this band [including its own characteristics: definition (number of pixels height x width), number of images that can be produced.
- Technology (active / passive imaging)
- Optics (which are used to focus the light, but pay attention to the optic matter according to its frequency band => e.g. Glass - which blocks the far-infrared)
- Lighting (particularly in active imagining)
- The technical design needed for processing images (reconstruction and improvement of images from the sensor) and potential image analysis (extraction of information from images)
  - > Computing power
  - > PC or Embedded
  - > I/O - are there specific I/O (e.g. aviation, military etc.)
  - > Output required, interfacing with other systems
- Are different sensors needed in different frequency bands?
- Do images need to be merged from different frequency bands?
- Does the image need to be presented? Catalogued? Or both?
- Who is the image being presented to? A person? An Algorithm? Both?

COTS VS CUSTOM

For demanding projects in areas where any error could be fatal (aeronautics, military, space etc.), the COTS has difficulty fitting into a global system.

Below are some examples from personal experience along with various projects developed in aeronautics, military or space:

Image pre-processing:
The so-called «industrial» off-the-shelf cameras do not generally have complex image pre-processing on board (e.g. FPN correction, HDR, stabilization). And in complex systems with a very large volume of data to process, it is important to do it as close as possible to the camera head. One can then use an FPGA which plays the role of «Data Cruncher».

Processing power and memory capacity :
When you need to develop an innovative application (e.g. an autonomous vehicle guidance system), you need to use professional sensors with very high performance. High performance means a very large volume of data captured in real time and therefore a high level of computing power is required to process and analyse this data. This can involve running image processing algorithms (for example optical distortion correction, auto exposure) or image analysis algorithms (detection, recognition, identification, tracking...). For example, a PC will be able to process one 12Mpx camera, but if the system consists of six 12Mpx cameras, one PC alone (even very powerful) will not be able to process the generated data flows. It will be necessary to use several in parallel, which will be far from optimal and efficient with bottlenecks sometimes on the computing power side, sometimes on the data flow level.

Form factor :
A COTS camera is already in an imposed format (both concerning the mechanical box but obviously also concerning the electronic boards which compose it). For some projects, the mechanical format of the electronic camera head boards must be specific to meet the size and shape requirements of the housing. For example, in a project where it is necessary to have several camera heads (eg: need to capture in different frequency bands or panoramic vision) it is possible to fit several heads in the same box and share pre-processing if necessary. The same applies to the cooling and management of the optics (mount, motorisation, autofocus...) which can be designed and optimised globally.

Interfaces: compatibility, robustness and bottlenecks :
There will always be compatibility problems between the COTS sub-elements of a global optronics system. These interfaces between elements, real «black boxes», always cost more in the end than custom design. Very often proprietary protocols will be imposed as a real brake in a global vision system. Similarly, certain constraints related to the camera's working environment (e.g. vibration inside a helicopter) can lead to the creation of custom transmission protocols for high-speed cables. Finally, some proprietary interfaces can constitute real bottlenecks, whereas in a system designed globally, everything is more fluid and optimized. Not to mention the latency in the transmission between the shooting and its processing, which can be crippling in some cases (pilot assistance, for example).

Power consumption and cooling :
The power consumption of an optronics based on COTS cameras will be higher than a custom architecture, even though image pre-processing is not done on board COTS cameras. In a tailor-made system, the need for electronic components is optimised to the bare minimum, thereby reducing consumption and heat emission.

Breakdowns, maintenance and responsibilities :
By thinking about the design of a project in a global way, we eliminate useless maps that interface the different ecosystems, and therefore potential problems of breakdown, problems of finding responsibility and maintenance of the global system. In the end, its reliability is increased.

About Nexvision

A global expertise on the whole vision system chain and a short integration process of latest technologies !

Nexvision is an independant, innovative and successfull design house for electro-optics systems.
From FPGA electronic design to mechanical and optical design along with embedded vision software, Nexvision covers all technics with an agile team able to integrate a transversal expertise in a global approach.
Exploration of new technologies is our DNA, and we integrate the entire design and integration scheme in our core activity.

DEFENSE & SECURITY

INDUSTRIAL INSPECTION

AEROSPACE

MEDICAL

NEXVISION AT A GLANCE

- A team of **30** engineers
- **16** years of existence and innovation
- **6** expertise pools : electronics, logic design on FPGA, optics, mechanics, embedded software & computer vision
- **25** core technical expertises
- A presence in **4** continents (North America, Europe, Africa, Asia)
- Headquarter : based in Marseille, south of France

KEY PARTNERS

NVIDIA, PHOTONIS, XILINX, SONY, microoled, CNRS, Texas Instruments, Samsung

Our design house : your best partner to design high-end innovative vision systems

For more than 16 years, we have been designing highly innovative vision systems for major clients with our most advanced technology to allow them to keep one step ahead with a lower risk. We are an outsourced R&D office for big companies.

« To integrate a non mature but promising technology in our system is always a risk. NEXVISION with its explorer temperament allows us to assess the viability of a new option by testing it themselves first. Then, we can be sure that what they propose is beyond the state of the art and functional. That really makes the difference. »

CLIENTS

Airbus Helicopters, Naval Group, Thales, Airbus, Zodiac Aerospace, Thales Alenia Space, CNES, DGA, Renault Nissan, Latécoère, Zeiss

Our products : a range focussed on situational awareness

Nexvision also develops its own range of products centered around situational awareness. Designed mainly for defense and security applications, these products carry the best of our know-how and the latest technologies straight out of the laboratories.

Keywords: night vision, panoramic vision, augmented reality, multispectral gyrostabilized gimbal, laser projector, sensor fusion.


EXTREM OWL


GSG-9/11


DIGITOWL


PANOMIX


PANOSPOT


SLBS

INTERFACES

Name	Type	Applications / usages				Mode	Max definition Frame rate	Possibility of chan-ging on fiber optic	Max lenght	Comments	Advantages	Disadvantages
		Capture	Display	Commu-nication	Storage							
Analog (PAL, NTSC, RGB)	analog	x	x			Unidirectional	720p30			interface history used for certain camera modules and displays	simple	low définition, low quality
HDMI (1.3 - 1.4)	digital		x			Unidirectional	10 Gbits/s (8Kp30)		5m max	video screen interface general public	popular	general public quality (not great for profes-sionals)
HDMI (2.0 - 2.1)	digital		x	x		Unidirectional	18 Gbits/s (8Kp60)		3m max	video screen interface general public	popular	general public quality (not great for profes-sionals)
MHL 1.1	digital		x			Unidirectional	2,25 Gbits/s			video screen interface general public	HDMI simplifié sur connectique micro usb3	not common, limited output
SDI (12G-6G-3G-HD-SD) IN/OUT	digital	x	x			Unidirectional	12/6/3/1.5/0.27 Gbits/s	yes	depends on cable and desired output	professional video inter-face (video cameras and screens)	simplicité, faible latence	only video interface
CoaXPress IN/OUT	digital	x	x	x		Full-duplex	6 Gbits/s - 21 Mbits/s		depends on cable and desired output	industrial camera interface	interface complète sur 1 seul coaxial (vidéo + données bi-direction-nelles + alimentation)	cost, complexity
Ethernet 100Mbits/s	digital			x		Full-duplex	100 Mbits/s	yes	100m			
Ethernet 1Gbits/s	digital	x		x		Half-duplex	1 Gbits/s	yes	100m		popular	limited output, latency
RS232 / RS485 / CAN / ARINC 429	digital			x							popular	limited to commands of low output
PCIe (Gen 3.0) x1/x2/x4/x8/x16	digital			x		Full-duplex	80 Gbits/s (5 Gbits/s per lane)	yes	local PCB (some cm), 100m with FO	allows interfacing between FPGA and CPU (between components)	très haut débit	cost, complexity
USB 2.0	digital			x	x	Half-duplex	480 Mbits/s		5 m	external interface		
USB 3.0	digital	x		x	x	Full-duplex	5 Gbits/s		5 m	external interface	popular	latency
(µ)SD / SDHC / eMMC	digital				x		100 Mbits/s		local PCB (some cm)		popular	
SATA III	digital				x		6 Gbits/s		1 m		popular	limited written output
NVMe	digital				x		24 Gbits/s writing		local PCB (some cm)	quick storage on SSD	haut débit d'écriture	new standard
MIPI CSI	digital	x				Unidirectional			local PCB (some cm)	smart phone/tablet camera interface	miniature interface	low distance
MIPI DSI	digital		x			Unidirectional			local PCB (some cm)	smart phone/tablet camera interface	miniature interface	low distance

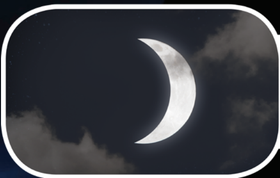
NEXVISION
OPTRONIC DESIGN

NIGHT LEVELS

DAYLIGHT ▶ *Dark limit of civil twilight under a clear sky*
More than 1 Lux

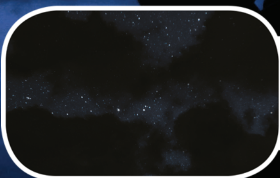
LEVEL 1 ▶ *Full moon on a clear night*
40 mLux to 1 Lux

LEVEL 2 ▶ *Full moon on a cloudy sky*
10 mLux to 40 mLux



LEVEL 3 ▶ *Quarter moon*
2 mLux to 10 mLux

LEVEL 4 ▶ *Dark, moonless, night sky (starlight)*
0.7 mLux to 2 mLux



LEVEL 5 ▶ *Very dark, moonless, overcast night sky (starlight) «can't see your hand in front of your face»*
100 µLux to 700 µLux

LEVEL 6 ▶ *Deep dark*
< 100 µLux

NEXVISION
OPTRONIC DESIGN

Want more ?

www.nexvision.fr