Data Acquisition

for Endoscopic images that contain:

Fog, Smoke, Staining and other Noise

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1 Idea

1.1 Motivation

The motivation to create this kind of data is given by the fact that there are only few free and open videos of laparoscopic surgeries, that show smoke or other adverse effects on the camera, since they exactly counter what a surgeon usually wants to archive: *a clear vision on the patients internals*. This document therefore describes the creation of *hazy, foggy, blurry and stained* endoscopic images and videos.

1.2 Primer

The objective is to create data in a custom setup, outside of the body of any creature. This series consists of a capturing setup and multiple iterations of data grabbing, with different documented changes to the environment as well as to the cauterized objects.

The archived data will contain a set of **videos** and **images** that show *noise*. This noise is defined by:

surgical smoke
Surgical smoke occurs when surgeons cauterize organs, veins or other body internal objects. Although it contents are mostly steam, there are multiple other particles dispensed within this kind of Fog. Mostly the leftovers of the cauterization given by the explosion of the cell. This releases all the cells contents, including tentative bacteria into into the pneumoperitoneum. [Tom08]
Depending on the time, type and tissue of the cauterization the smoke can vary in its aspect, also the carbonisation level of the tissue influences the smoke and its aspect.

haze
Haze is a effect that also appears alongside to cauterization, the heat of the surgical cauters leads to the vaporization of body liquids. This leads to fog, steam and haze that can block the direct vision to the targeted areas and also can build a thin film on the endoscopes objective, as well as *staining* which shows up as the formation of drops on the objectives.

staining
Multiple body internal fluids get directly in touch with the endoscopes objective. These fluids gather to build drops, which blur or cover certain parts of the cameras vision.

1.3 Objective

All of the above mentioned effects are required to occur withing the generated test data, as it would be the case in a real surgery. The Quality of the images should be quite

high, since typically used endoscopes in modern surgery often have high frame rates (above 60FPS) and resolutions of more than 4K2K (4000x2000 Pixels). src?
The produced data focuses on a setup that is as close as possible to a real surgery.
The quality of the images is therefore just a secondary goal. More important is the creation of videos, as well as images that contain multiple combinations of the given pollutions.

2 Preliminaries

2.1 fundamental papers

The Paper [SBZB94] introduces a learning method for expectant surgeons to practice without living patients, be it human or animal. Since these surgeries are expensive, time consuming and moreover they need to be authorized by governmental or veterinarian institutions in the European Union.

The data generation of surgical smoke and artefacts requires the use of organic material that can be cauterized. Porcine visceral organs are very similar to human visceral organs which the paper [SMH+11] postulates and are therefore a appropriate candidate for the test setups.

Surgical smoke is different to "normal" smoke because of its contents and their composition as given by the paper [Ulm08]. Therefore the generation of the test data needs to be performed with a special focus on the realism of the smoke and haze. Also not only the cauterized organs and their humility are important to the aspect of the smoke. According to experts also the method as well as the duration of cauterization is an important influence on the smokes quality.

Laparoscopic trainers are often used in eduction and training of future surgeons. Therefor a source for the setup of these kind of trainers and how they should look like is taken from the papers [SBZB94] and [UHB+].

2.2 Requirements to the resulting data

The resulting data needs to fulfill several requirements, mostly concerning the occurrence and mixture of pollutions the as well as the quality of the images.
Investigated Pollutions are:

- Surgical Smoke
- Haze
- Staining
  - Blood
  - Water
  - Lipids

With these problems in mind the most critical of them need to be selected and further investigated.

2.3 Selection

The following section deals with pre-testing thoughts on the Organ / Animal selection

Host Animals

1. domestic Pig (Sus scrofa domesticus) *referred as Porcine*
2. cattle (Bos primigenius taurus) *referred as Bovine*
3. house Mouse (Mus musculus)

The enumeration given above lists possible candidate animals for the organs. Due to practical reasons only the 3 of them are getting into a closer selection.

Mice have a quite high similarity to the human body, but problems occur in the availability and the handling of these organs. Therefore Mice's organs drop out, since they are expected to have a bad handling due to their small size.

Porcine Organs fit better for this purpose, but especially their internals are not very commonly consumed. For closer testings it is expected that porcine organs are necessary, while for first setup tests or technical evaluations other organs might be sufficient.

Bovine Organs are the most commonly available visceral organs, since they are often used in culinary way. Tripes or livers especially. Although their similarity to human internals is not that high, their advantages in availability and usability makes them a good choice for first experiments.

As given in [SMH+11], the common domestic pig has already often been used as the major species for animal testing of both pharmaceutical and surgical experiments. Due to the fact that pigs have a lot of similarities to the human body, e.g. the resemblance of their cardiovascular systems or the digestive systems.
Concluding to this, the data should contain a set of video footage that is based on the cauterization of porcine internals.

Organs The most laparoscopic surgeries are performed in the area of the abdomen, so the most reasonable things to use as target objects for the cauterization would include:

- Gallbladder (Vesica fellea)
- Liver (Hepar)
- Stomach (Astomagus)
- Gastrointestinal tract (Tractus digestorius)

The Selection of Organs depends on similar choices as the selection of animals. The decision is based on their availability and usability, countering to real surgeries like liver resections or Cholecystectomies.

Another point is the internal moisture that is given by mucous membranes, their cauterisation leads to fog and steam. This issue needs to be considered since moisture is expected to create foggier images that therefore are closer to real surgeries within wet environments.
This moisture occurs in forms like Blood, lipid and other body internal fluids. The heating of these lipids generates different kinds of smokes, l[illegible]s and fogs, depending on the lipid.
Based on this information, the insertion of these lipids needs to be considered within the setups.

3 Setup

As the Prototypes improve the quality and realism of the images are improved to create test data as reaslistic as posslible.
This section holds information about the setups of the Data generation.

3.1 Setup 1

The first prototype is designed to be a "pr[illegible]of concept" - the general setup will be tested with minimal effort on the realism, but a focus on the equipment, its usability and the suitability for future tests and data generation.

3.1.1 Hardware setup

Capturing Setup
Within this phase multiple cameras are be tested regarding their usability, these Cameras are:

Table 1: Cameras under Test

Company	Model	Resolution	REF
Nikon	D3400	6000x4000px	[Nik16]
Logitec	C270	1280x720px	[Log10]
Alcor Micro	SJ00446-01	1280x720px	NONE?

Missing China-CAM Datasheet

Temperature and Humility
To keep the setup as close as possible to real surgeries the temperature and humility need to be monitored and even better regulated. Therefore measurement devices will be placed inside of the testing environment.
For the first prototype the no temperature or humility actor's will be used to improve the realism of the setup.
The sensor setup is ought to be tested for its usability - especially within terms of the connection through the test boxes walls.
The sensor board is a "self-made"-PCB that contains a ESP8266F [Esp18] and the HDC1080 from TI [Tex16]. The ESP8266F creates a wireless connection to the capturing Computer and distributes the data of the HDC1080.

Cauter
For the Prove of concept setup no medical cauter is used, due to availability. The cauters substitutional device is a simple soldering iron, manufactured by Weller [Wel02]. The soldering iron is expected to act like a thermo-cauter. Modern surgery relies on electrical cauterization [ele04] because it has benefits on the carbonization of organic matter, leading to better healing of the incinerated area. Since the healing factor does not need to be considered the use of a thermal cauter is expected to be sufficient for the creation of surgical smoke.

3.1.2 Target

Organ The first Organ that will be tested is a bovine liver, out of its pure availability on the open Market.
The Organ is placed on a dish inside of the box and is incinerated with the above mentioned soldering iron as a cauter.

externals The Box is closed over the whole generation time, so no smoke can leave the laparoscopic setup. Also the Box is completely left "as is" no cuts, holes or other modifications are performed on the box. Because of the convenience of the Wireless connection through the boxes walls the only insertion from outside is the power supply of the soldering iron.
Within this test setup no Blood or other liquids are used, since this prove of concept operates as a testing environment for the sensors, the cauter and the cameras.

3.1.3 Expectations

repair pro / con titles

DSLR
With a high resolution and frame rate this camera is expected to deliver the highest quality shots of the Setup.

Advantages

- High Quality images
- High Frame Rates

Disadvantages

- No close up recording

Webcam
The Webcam setup is a more minimalistic camera to be compared to the DSLR camera. The data created by the Webcam should create a contrast to the DSLRs high-quality videos, showing the impact of higher frame rates and resolutions on the effect of the Algorithm.

Advantages

- comparable images

Disadvantages

- No close up recording

Endoscope

The Endoscope cam promises to give good results regarding the creation of staining on the cameras lens as well as the pollution with steam settling down on the objective of the camera.
This small will be placed close to the incineration area so a strong pollution can be expected.

Advantages

- placeable close to the Organ

sadvantages

- bad Frame rate and Image quality

Focus of this Prototype is the image quality concerning smoke, haze, and staining. Since the setup is static, which means that none of the cameras or objects are being moved through the capturing of the video data. Also the handling of the Camera-setup and the cautering device is evaluated and expected to be a improvable topic over the upcoming prototypes.

3.2 Prototype 1

As the Figure2 shows, multiple cameras are used at the same time to capture comparable videos of the same scenario.
The following explanations fit for both the setups schematic 1 as also for the picture of the setup 2.

REF	Device	Description
1	Raspberry PI	controlling element
2	DSLR	Main Camera
3	Webcam	USB-Camera
4	Endoscope	close up shots
5	Environmental sensor	Temperature / Humility
6	Soldering Iron	improvised cauter
7	LED light	controlled light source

Table 2: number references for Images 1 and 2

3.3 Result

The results of the first testing setup are about 2.6GB of Video data containing 5 Iterations of incineration attempts from 2 different perspectives, filmed by 3 different cameras.

3.3.1 generated Data

Video Data

The following Pictures are taken out of the Videos form the fifth and final video generation iteration.
They represent the best setup but contain the already quite heavily damaged liver that suffered from the previous tests.

Figure 3: DSLR output V5

The DSLR results are as expected the qualitatively best ones, with a stable frame rate and high resolution

Figure 4: Endoscope camera output V5

Figure 5: Webcam output V5

All of these pictures have been taken in the same testing iteration within a range of 2 seconds, so the show the same situation.
Noticeable is that haze intensity appears to differ, depending on the resolution of the camera.

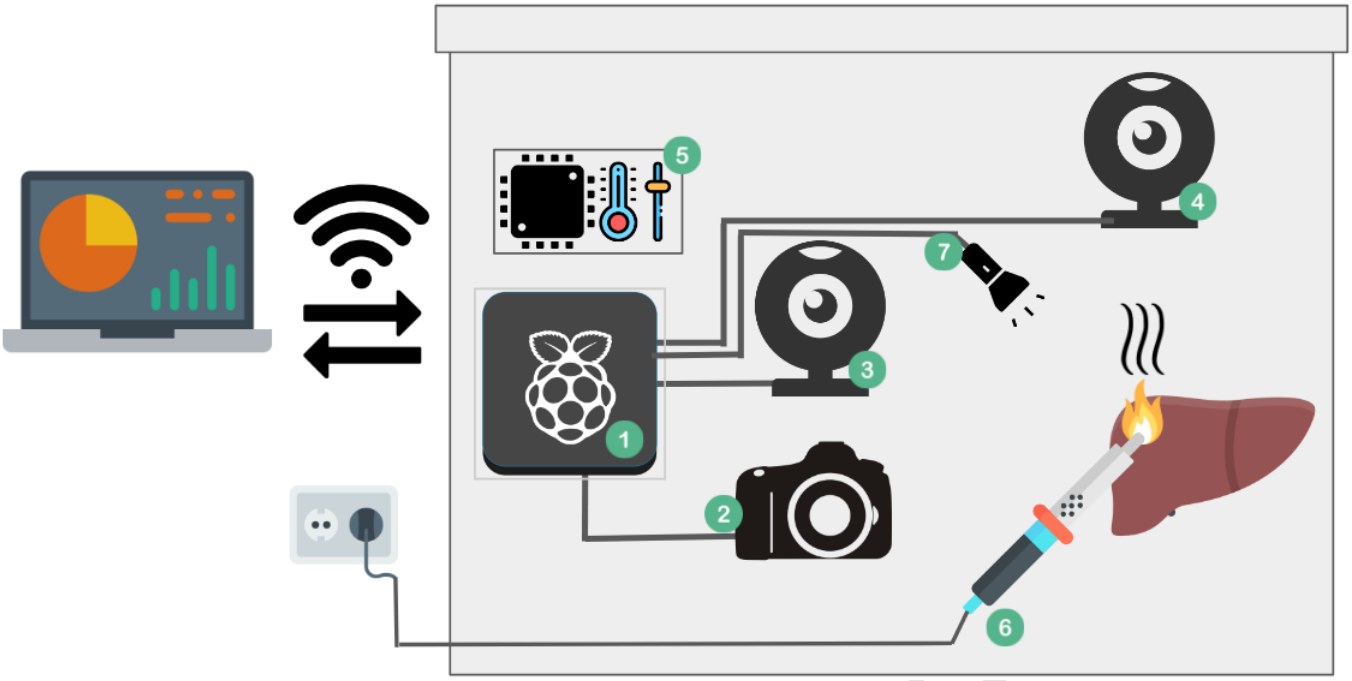

Figure 1: schematic of the first setup

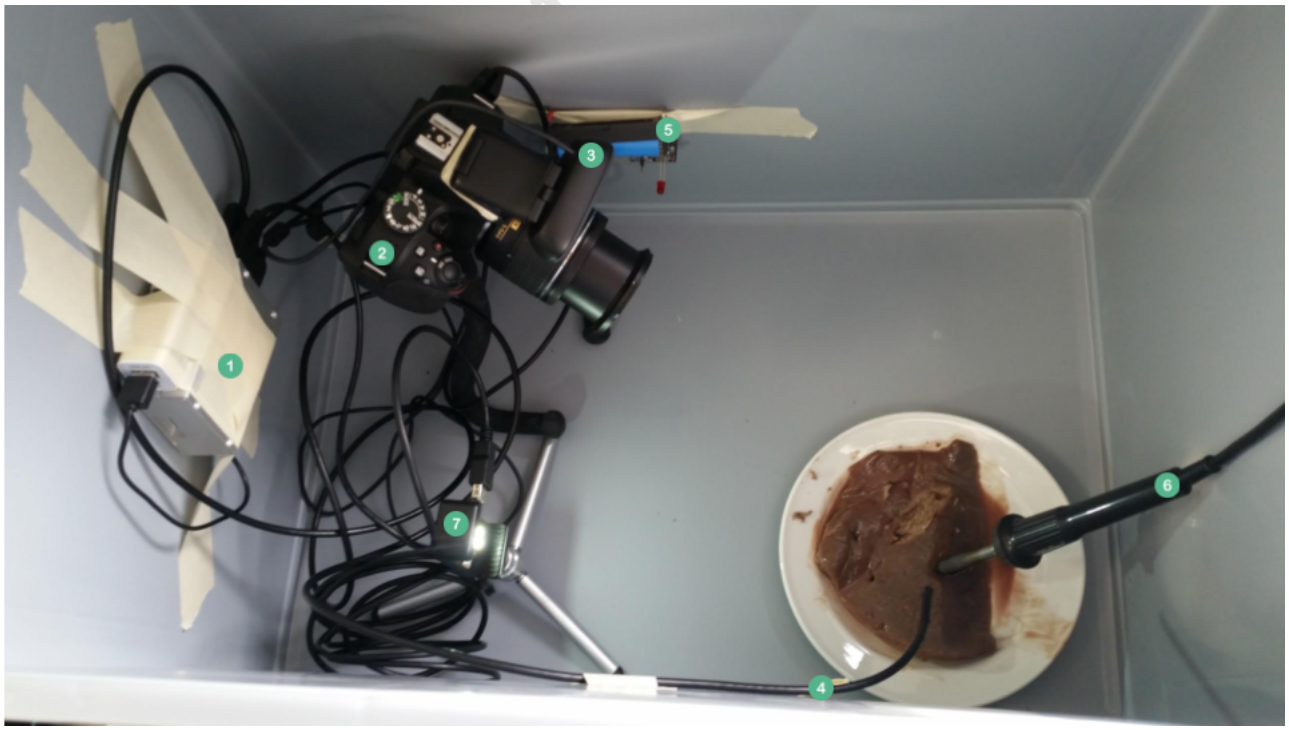

Figure 2: real setup of video generation V1

Temperature Data

Temperature data given format

mention the self heating effect of the PCB....

3.3.2 evaluation

Critical View

Bad staining - haze only in some images - frame tape visuals

good results with soldering iron - for haze

Conclusion

Even though the results lag behind the expectations, the produced data gives video files about smoke in a proper environment. A use for the implementation of a smoke detection algorithm is still considerable, while the use as evaluation data might not be appropriate.

3.4 Setup 2

The second setup focuses on the elimination of the Errors which where encountered in the previous prototype. This mainly focuses on the replacement of the Cameras as well as using a none-static working environment with a real moving endoscope.

Improvements

Non static Setup - Self-made Endoscope Trainer

Use of Box with neoprene top to be pierced by the tools.

Pics!

REF	Device	Description
1	Endoscope	capturing device
2	Neoprene layer	simulates pierce able skin
3	Objective	combines Camera and Lighting
4	Soldering Iron	improvised cauter

Table 3: number references for Images 1 and 2

Table corresponds to schematic6.

3.4.1 capturing Setup

Hardware Setup

Cauter

Temperature and Humility

3.4.2 Target

Organ

Externals

The externals have been reconsidered so that the setup no is no longer static. Therefore the Testing box has been manipulated to create some kind of *laparoscope trainer* as they are used to train upcoming surgeons under praxis close conditions.

This setup now includes a Box that is primed with holes that are covered with a neoprene layer to create a skin like surface through which the endoscopes can be inserted.

3.5 Prototype 2

3.6 Setup 3

The third setup generates data that is only going to be used as a reference, but not for the development of the algorithm. This should face the problem of over fitting of the Algorithm.

3.6.1 capturing Setup

Hardware Setup

Cauter

Temperature and Humility

3.6.2 Target

Organ

Externals

3.7 Prototype 3

4 Results

In Progress

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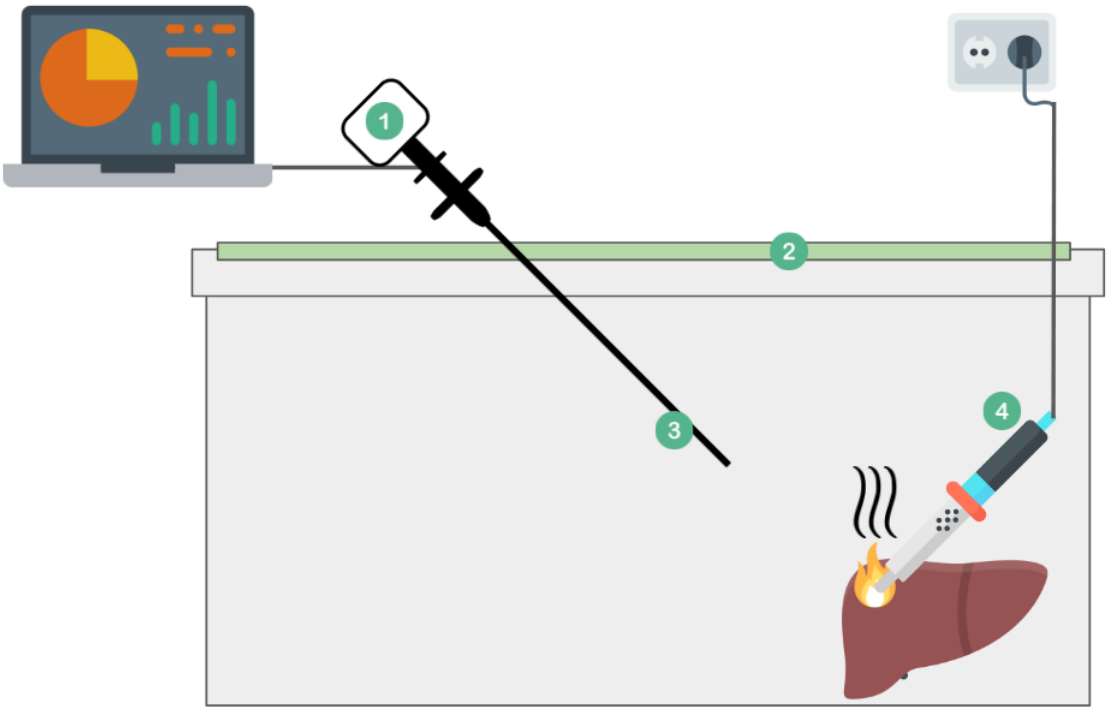

Figure 6: schematic of the second setup