

# Video Analysis Supporting Stroke Assessment within the Prehospital Care

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# Abstract

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Sweden, as well as the rest of the world has an increasing life-expectancy creating higher demands on the healthcare providers and on the quality of healthcare. Stroke is the third leading cause of death in Sweden. Prehospital stroke assessment is completed as rapid assessments by paramedics through the use of different stroke scales. Current stroke scales exclusively include qualitative data which results in a low sensitivity of the scales, thereby creating an over-triage of patients. Interrater variability is high, meaning different professionals conclude different assessments for the same patient.

The time until treatment after a stroke is essential for the outcome. The faster a diagnosis can be determined the faster the patient can receive care. The paramedics have a large impact on the time from first care contact until diagnosis; therefore a correct stroke assessment is of immense importance.

The aim of the thesis is to create a conceptual clinical support system to reduce the over-triage and interrater variability. The conceptual system produced is referred to as the suggested system. The suggested system includes video analysis of stroke patients in order to establish a more equal, patient oriented and knowledge based care.

The suggested system detects four important parameters of stroke assessment. The parameters are extremity motor skills, facial-, eye- and head-movements. The four parameters cover eleven out of fifteen factors currently used to perform a stroke assessment at a hospital. The stroke scales used at hospitals are more extensive and detect larger varieties of strokes than prehospital stroke scales. The use of more extensive and accurate stroke scales in the prehospital area has previously been too time-consuming to complete.

The output of the suggested system visualises an augmented reality that enhances the assessed parameters resulting in a positive stroke assessment, which provides support to paramedics and on-call doctors.

The suggested system includes hardware and software placement and requirements as well as complexities with implementing new technologies and solutions in the prehospital care. Further discussed is the understanding of the single user as well as the integration of a novel system. The collaboration between hospitals and the prehospital environment is crucial for determining consequences, possibilities and difficulties in enhancing the current pathways of stroke assessment.

**Keywords:** Augmented reality, FAST, NIHSS, prehospital care, quantitative measurements, stroke, telestroke, video analysis.



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### Approval

The figures 2.2-2.4, 2.7, 2.8 presented in the report have been reused from their original publications. The figures have been approved for usage in the report by Riksstroke, see figures 2.4, 2.7, 2.8 and by the National Institute of Neurological Disorders and Stroke, NINDS, see figures 2.2, 2.3. The author has a written approval from Riksstroke and NINDS. All other figures in the report are figures created by the author.



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## 1.1 Aim

The aim is to reduce the interrater variability and over-triage of current prehospital stroke assessments by examining the possibilities of implementing digital video analysis for stroke assessment in the prehospital care.

The users' needs and the possibilities of quantifying currently used parameters of stroke assessment should be investigated to fulfil the aim. Insight to improvement of health, work relations and time deduction should be investigated. Risks, legislation and complications with a semi-automated system should be discussed and a conclusion of how the research could be improved for further use should be made. The result of the thesis should be a conceptual model of a suggested system.

It is important to understand that the system should not replace a human but instead support the user's decision. The paramedics have knowledge about stroke assessment, but due to low sensitivity of current stroke scales over-triage is recommended to avoid inaccurate assessment.

To attain the aim it was divided into three smaller sections.

- To collect data.
- To analyse and interpret data.
- To create specifications of a conceptual system.

The layout of the thesis is a pilot study. The collection of data is based on interviews, observations and literature studies exploring the possibilities of developing a video-supported system for stroke assessment in the prehospital care. The collected data describes how stroke assessment is currently completed and identifies signs connected to stroke. The analysis of the collected data should determine what variables affect the interrater variability and research the current stand point on digital assessment of stroke. The analysis determines if parts of the data can be quantified and it includes specifications of functions as well as technology. A summary of implementation in the prehospital care as well as the layout of the suggested system is determined in the specifications of the conceptual system.

## 1.2 Abbreviations

<b>ABCDE</b>	Airway, Breathing, Circulation, Disability and Exposure
<b>ACA</b>	Anterior Cerebral Artery
<b>AR</b>	Augmented Reality
<b>AVM</b>	Arteriovenous Malformation
<b>CSC</b>	Comprehensive Stroke Centres
<b>CT</b>	Computer Tomography
<b>DNT</b>	Door-to-Needle Time
<b>ECG</b>	Electrocardiogram
<b>EHR</b>	Electronic Health Record
<b>EMG</b>	Electromyography
<b>EMR</b>	Electronic Medical Record
<b>EMS</b>	Emergency Medical Services
<b>EMT</b>	Emergency Medical Technician
<b>EPR</b>	Electronic Patient Record
<b>ER</b>	Emergency Room
<b>FAST</b>	Face, Arm, Speech Test
<b>ICP</b>	Intracranial Pressure
<b>ICT</b>	Information and Communication Technology
<b>ICU</b>	Intensive Care Unit
<b>IoT</b>	Internet of Things
<b>IR</b>	Infrared
<b>ISO</b>	International Organisation for Standardisation
<b>IV</b>	Intravenous
<b>MCA</b>	Middle Cerebral Artery
<b>MDR</b>	Medical Device Regulation
<b>mNIHSS</b>	Modified National Institutes of Health Stroke Scale
<b>MRI</b>	Magnetic Resonance Imaging
<b>MSU</b>	Mobile Stroke Unit
<b>NDA</b>	Non-Disclosure Agreement
<b>NHS</b>	National Health Service
<b>NIHSS</b>	National Institutes of Health Stroke Scale
<b>PCA</b>	Posterior Cerebral Artery
<b>preHAST</b>	preHospital Ambulance Stroke Test
<b>RETTS</b>	Rapid Emergency Triage and Treatment System
<b>SDK</b>	Software Development Kit
<b>TIA</b>	Transient Ischemic Attack

The theory describes stroke in general, how stroke is assessed and the Swedish healthcare sector in order to create an overview of factors affecting prehospital stroke assessment.

## 2.1 Stroke

Stroke is the world leading cause of chronic disability and the third most frequent cause of death in Sweden. Every 17th minute a person in Sweden suffers a stroke. High patient numbers, many different stroke mimics, restricted stroke expertise and geographical limitations affect the outcome of stroke assessment within the prehospital care. [1, p. 12], [2, p. 55]

Stroke is a disruption of blood flow through the brain caused by a haemorrhage or an occlusion. An occlusion of a vessel, called an ischemic stroke, is the most common type of stroke. 85% of all strokes are ischemic strokes, 10% are intracerebral haemorrhages and 5% are subarachnoid haemorrhages. A haemorrhagic stroke is a bleeding.

The effects of stroke are visible through loss of functions otherwise controlled by the brain. Risk parameters for stroke can be seen in table 2.1. Stroke is most common in patients older than 75 years. [2, pp. 14, pp. 25-26, p. 61], [3]

Every minute spent with untreated stroke, 1.9 million neurons die. Therefore, time is of the biggest importance when diagnosing stroke. “Time is brain” is an expression often mentioned in combination with stroke care. The expression highlights the importance of decreasing the time from symptom onset until care is given. Another such expression is the Door-to-Needle time, DNT, which describes the time from arrival at a hospital until care is given. The prehospital care is often the first care contact for a stroke patient, giving the paramedics a large ability of decreasing the time until treatment. [2, p. 87], [4]

Stroke patients collectively demand over one million care days per year, making stroke the somatic condition that causes most number of hospitalised days per year in Sweden. Among many hospitalised care days, stroke patients often need after care such as rehabilitation, care at nursing facilities and municipal assisted service facilities. This leads to stroke being the most expensive condition treated by the Swedish healthcare. [5]

Nearly 20% of all stroke patients die within the first 90 days. More than 50% of the survivors become partly or fully functionally dependent for the rest of their lives. 80% of stroke patients suffer hemiparesis, i.e. weakness to one side of the body. Dysphagia, which is difficulties with swallowing as well as Aphasia and Dysarthria

which are speech reductions are other common stroke signs. Hemi-anaesthesia, i.e. numbness, is another physical effect of stroke but it is also common that a stroke affects the emotional parts, causing a depression. Fatigue, seizures, vision loss, cognitive limitations, memory loss and pain are known effects, see many more in table 2.2. The signs of a stroke are often life-long lasting reductions. Most patients suffer from more than one of these reductions. [2, pp. 11-16, pp. 165-176], [6]

Previous Stroke	Stenosis in Neck Arteries
TIA	High Cholesterol
Atrial Fibrillation	Genes
Diabetes	Blood Sugar
High Blood Pressure	Smoking
Lifestyle	Stenosis in Neck Arteries
Temporary Loss of Vision	Head Trauma

**Table 2.1:** Risk parameters for stroke.

Aphasia	Neglect
Loss of vision	Dysarthria
Hemiparesis	Facial Hemiparesis
Hemi-anaesthesia	Flickering Vision
Fever	Blood Sugar
Dysphagia	Headache
Dizziness	Vomiting
Neck Pain	Loss of Coordination

**Table 2.2:** Signs of stroke.

99% of all stroke patients are diagnosed by interpreting images from a computer tomography, a CT-scan. A CT-scan displays haemorrhages clearly, but occlusions are harder to detect. 24% of stroke patients require a magnetic resonance imaging, MRI, for further investigation before a diagnosis can be determined. MRI is used when a diagnosis is uncertain after a clinical assessment and a CT-scan. Other methods include ultrasound, CT-angiography and long-time electrocardiogram, ECG, registration. To have a diagnosis is extremely important. Before this is done no treatment can start. The diagnosis methods can only be completed at a hospital and not in the prehospital care. [2, p. 31, pp. 83-87]

## 2.2 Stroke Scales

There are multiple scales for stroke assessment and measuring stroke outcome. The scales have different complexity and are used to detect different parameters. Some scales are used to detect early signs of stroke whereas other scales are used to predict the possibilities of recovery after a stroke. The focus will be on stroke scales for early detection of stroke signs, other scales mentioned are to emphasise why they are not continually discussed. The sensitivity of an initial stroke assessment using stroke

scales has been validated to vary between 50.0-96.6%. The vast amount of different stroke scales and workflows increase the uncertainty of the assessment. [7] – [10]

Paramedics usually use a rapid protocol to triage stroke and other neurological disabilities at the scene. The rapid protocols consist of three to eleven factors. The protocols most commonly used in the ambulatory care in Sweden are the Face Arm Speech Test assessment, FAST, and the modified National Institutes of Health Stroke Scale, mNIHSS. The protocol mostly used in Swedish hospitals is the National Institutes of Health Stroke Scale, NIHSS. There is a demand for a developed stroke scale including high sensitivity and an indicator of stroke severity. [11]

### 2.2.1 FAST

FAST is an acronym for Face, Arm, Speech and Time, which are four critical factors in stroke detection. The three first factors refer to facial and arm weakness as well as speech loss. Time is to imply that time is of big importance for the predicted outcome, sometimes "time" is exchanged for "test". [12]

Table 2.3 displays the FAST assessment. The Act FAST campaign was launched in 2011, see figure 2.1. The aim of the campaign was to increase the awareness of stroke and Transient Ischemic Attacks, TIA, to the population by introducing a general assessment tool. The campaign is thought to have improved the outcome after a stroke during the last years. [2, p. 24] [13]

Since FAST only includes three factors it is a rapid method. Other scales contain more factors but more factors used in FAST have been concluded to prolong the time more than the performance. FAST is especially developed to be used in a prehospital environment. FAST is popular because it is easy to learn, easy to use, reliable and consistent, but it is criticised for not being general in its assessment as well as not determining the severity of stroke. FAST is created to screen exclusively for the most common stroke, called a large vessel occlusion, therefore few parameters can be used. [14], [15]

The usage of FAST is described below. If at least one element is determined as *YES* when assessing the patient the scale indicates a stroke or a TIA. [9]

<b>FAST - Face Arm Speech Test</b>			
Speech Impairment	<input type="checkbox"/> YES	<input type="checkbox"/> NO	<input type="checkbox"/> ?
Facial Palsy	<input type="checkbox"/> YES	<input type="checkbox"/> NO	<input type="checkbox"/> ?
Affected Side	<input type="checkbox"/> L	<input type="checkbox"/> R	
Arm Weakness	<input type="checkbox"/> YES	<input type="checkbox"/> NO	<input type="checkbox"/> ?
Affected Side	<input type="checkbox"/> L	<input type="checkbox"/> R	

**Table 2.3:** FAST - Face Arm Speech Test

#### **Facial movements**

Ask the patient to smile or show teeth. Identify unequal smile or grimace or if the patient shows obvious asymmetry.

#### **Arm movements**

Ask the patient to lift both arms to 90 degrees if sitting or 45 degrees if standing and to hold the position for 5s. Identify if an arm falls down or drift within these 5s.

#### **Speech**

Identify slurred speech and word finding difficulties. Ask the patient to name some

objects nearby such as a cup, chair, keys etc.



**Figure 2.1:** The Act FAST campaign.

## 2.2.2 NIHSS

The National Institutes of Health Stroke Scale, NIHSS, consists of 15 factors, shown in table 2.4. The 15 factors are qualitative measurements of a standard neurological examination. NIHSS is increasing in use both as an initial assessment tool but also as a tool for planning post-acute care. Four factors out of these 15 have been reported to decrease the scales validity and reliability. Therefore a modified NIHSS scale called mNIHSS has been introduced. The four factors removed in mNIHSS are level of consciousness, facial weakness, Ataxia and Dysarthria. [11]

The NIHSS scale is designed as an observation scale. Since there is a protocol to follow this method is good to use for non-expert professionals such as paramedics, but due to the vast amount of tests it is too time consuming to carry out in the prehospital care. The factors are well known to other professionals, creating a common terminology which saves time in triage and treatment. Nurses that work bedside the patient may use NIHSS as a tool to monitor the progress of the condition. NIHSS is a score based scale measuring stroke severity as well as screening for many types of stroke, where the maximum score is 42. A score less than five usually results in the patient being sent home, scores between 6-13 indicate long time rehabilitation and a score above 14 often lead to long time care at a nursing facility. [11]

Questions asked according to NIHSS concern the current month and the patient's age. Since the test is standardised the questions, commands and instructions are always the same. The commands given are to open and close eyes, make a fist and relax. The gaze is tested by asking the patient to follow the paramedic's finger movement in a horizontal line. The facial palsy is tested by asking the patient to show teeth, close eyes and raise eyebrows.

Ataxia is in-voluntary coordination of limb movement. To test Ataxia the patient is asked to meet the fingertip of the paramedic and thereafter to touch his or her own nose. The patient is also asked to place his or her heel on the opposite knee and slide the heel downwards. The sensory tests can be made by the paramedic pressing a pen to proximal and distal parts of the limbs. [16]

Language is tested throughout the entire assessment and by describing the NIHSS picture and naming sheet, see figure 2.2 and figure 2.3. Dysarthria, the articulation and clarity of speech and Aphasia the understanding of words are tested by asking the patient to read the phrases on the NIHSS cards provided. The phrases can be seen in table 2.5. Extinction and inattention are tested to discover neglect or inattention. To test this the paramedic touches one side of the patient, asks which side that was and repeats the exercise. [16]

**1a Level of Consciousness**

- 0=Alert
- 1=Not alert, arousable
- 2=Not alert, obtunded
- 3=Unresponsive

**1b Questions**

- 0=Answers both correctly
- 1=Answers one correctly
- 2=Answers neither correctly

**1c Commands**

- 0=Performs both tasks correctly
- 1=Performs one task correctly
- 2=Performs neither task

**2 Gaze**

- 0=Normal
- 1=Partial gaze palsy
- 2=Total gaze palsy

**3 Visual Fields**

- 0=No visual loss
- 1=Partial hemianopia
- 2=Complete hemianopia
- 3=Bilateral hemianopia

**4 Facial Palsy**

- 0=Normal
- 1=Minor paralysis
- 2=Partial paralysis
- 3=Complete paralysis

**5a Left motor arm**

- 0=No drift
- 1=Drift before 10s
- 2=Falls before 10s
- 3=No effort against gravity
- 4=No movement

**5b Right motor arm**

- 0=No drift
- 1=Drift before 10s
- 2=Falls before 10s
- 3=No effort against gravity
- 4=No movement

**6a Left Motor Leg**

- 0=No drift
- 1=Drift before 5s
- 2=Falls before 5s
- 3=No effort against gravity
- 4=No movement

**6b Right Motor Leg**

- 0=No drift
- 1=Drift before 5s
- 2=Falls before 5s
- 3=No effort against gravity
- 4=No movement

**7 Ataxia**

- 0=Absent
- 1=One limb
- 2=Two limbs

**8 Sensory**

- 0=Normal
- 1=Mild loss
- 2=Severe loss

**9 Language**

- 0=Normal
- 1=Mild aphasia
- 2=Severe aphasia
- 3=Mute or global aphasia

**10 Dysarthria**

- 0=Normal
- 1=Mild
- 2=Severe

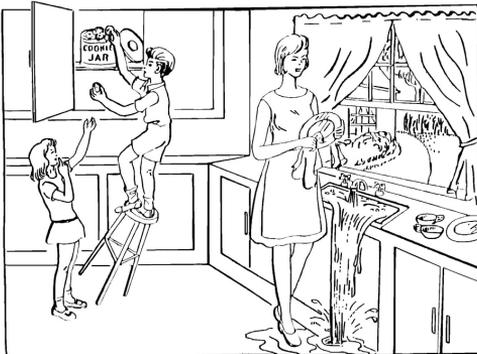
**11 Extinction/inattention**

- 0=Normal
- 1=Mild
- 2=Severe

**Table 2.4:** The 15 element NIH Stroke Scale.

Phrases testing Aphasia:	Words testing Dysarthria:
You know how.	MAMA
Down to earth.	TIP-TOP
I got home from work.	FIFTY-FIFTY
Near the table in the dining room.	THANKS
They heard him speak on the radio last night.	HUCKLEBERRY
	BASEBALL PLAYER

**Table 2.5:** NIHSS phrases for Aphasia and Dysarthria.



**Figure 2.2:** NIHSS picture used when examining Aphasia.



**Figure 2.3:** NIHSS naming sheet used when examining Aphasia.

## Other Methods

Other stroke scales are for example the Glasgow Outcome Scale, GOS, and the modified Rankin Scale, mRS which measure the outcome of stroke and the Barthel Index, BI, which is used to plan rehabilitation. The Stroke Impact Scale, SIS, was designed to add parameters of a patient's perspective on the effects of stroke. [11]

In the south of Sweden, in Skåne, another scale is used to assess stroke in a prehospital setting. The scale is called prehospital Ambulance Stroke Test, preHAST. PreHAST consists of eight items derived from the NIHSS. Mild or unusual stroke symptoms may be oppressed by preHAST but the scale has great sensitivity, which comes to a price of lower specificity. PreHAST is based on scores, just as the NIHSS, in order to both screen for stroke and grade the severity of a stroke. It is a general scale, screening for all stroke types, used in prehospital identification and notification of stroke. [17]

There are time optimization methods used in Sweden called stroke alarms. Stroke alarms are predetermined clinical pathways which involves on-call doctors guiding

the transfer of a patient when experiencing a suspected stroke. A stroke alarm can have a different layout depending on which county council it is adapted in, but all alarms have common aims. A stroke alarm notifies the affected units at the hospital, to enable a decrease of time until care. The method determines a standard way of transferring a patient, creating a flow from the ambulance to the stroke unit. [2, pp. 70-71]

The Swedish organisation Riksstroke suggests that all hospitals, and prehospital professionals should use the NIHSS or the mNIHSS in order to achieve a common terminology facilitating the communication and understanding between different stakeholders. [2, p. 62]

## 2.3 Guidelines for Stroke Treatment

Stroke treatment by admission of drugs, i.e. thrombolysis has to start before 4,5 hours after the first sign of stroke. If the treatment is surgical via catheter, i.e. thrombectomy the treatment has to start within 3 hours of first symptom. The time span is not globally standardised, but it recently became nationally standardised in Sweden. Recent research implies that drugs can be efficient up to 24 hours after first symptom. A thrombectomy is only performed at University hospitals. Sweden has nine University hospitals placed in Uppsala, two in Stockholm, Malmö, Lund, Gothenburg, Umeå, Linköping and Örebro. [2, pp. 86-105]

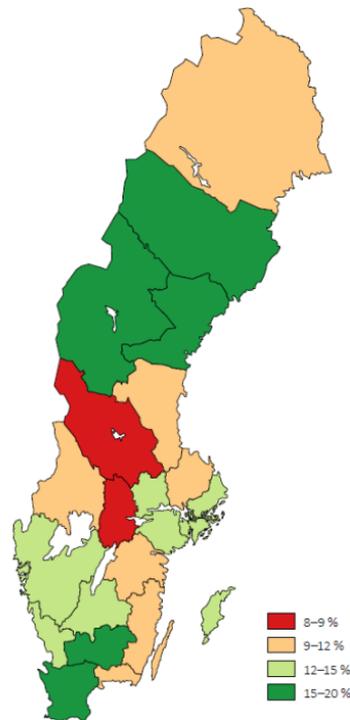
Many countries include treatment limitations concluding that patients over 80 years should not be given drugs. The limitation is set because elderlies are an untested demography and because elderlies in general are weaker than other patients. Sweden does no longer have a strict limit at 80 years, but a recommendation is still present. The overall time limit for drug or catheter based treatment is due to the unproven effect if the limited time has passed. [1], [18]

### 2.3.1 Treatment of Ischemic Stroke

Reperfusion treatment, to restore the blood flow after an ischemic stroke with thrombolysis or thrombectomy has continued to increase in use. Figure 2.4 shows the proportion of ischemic stroke patients who received reperfusion therapy per county in 2016. The low percentage of patients treated with reperfusion therapy is due to that too long time had passed before treatment could start, the onset of symptoms was unknown, the stroke was a haemorrhage, the symptoms were too mild or too severe or contraindications resulting in a treatment not being recommended. The percentage of stroke patients receiving reperfusion therapy can not be 100%, but as seen in figure 2.4 some county councils can improve the proportion. [2, pp. 67-74, pp. 82-106]

Thrombectomy is often used together with thrombolysis. Procedures include carotid endarterectomy which involves a surgeon removing plaques from the affected vessels to prevent repeated strokes. Another option is to use angioplasty and stents, involving a balloon expansion of the narrowed vessel. An artificial stent can be inserted to support the affected vessel. [3]

An ischemic stroke might introduce a brain swelling requiring a procedure called decompressive craniectomy to handle the swollen brain tissue. [2, pp. 67-74, pp. 82-106], [19]



**Figure 2.4:** The proportion of reperfusion therapy per county.

## Thrombolysis

Thrombolysis is also known as thrombolytic therapy. Thrombolysis regards injecting drugs into blocked vessels to dissolve blood clots and achieve a better blood flow. Thrombolysis can be performed by injecting drugs intravenously, IV, or through a catheter which delivers the drug directly to the site of the occlusion. Thrombolysis is used as an emergency treatment for heart attacks, pulmonary embolisms and strokes. Thrombolysis should be carried out as soon as possible. To ensure the dissolving of the cloth, medical imaging techniques are used. If the cloth is large the treatment might be ongoing for days. [20]

## Thrombectomy

A thrombus is defined as a solid mass stationary cloth, while an embolus is a cloth in motion. A thrombectomy is the removal of a thrombus. Thrombectomy is a catheter based procedure, where a catheter is inserted into the vessel near the occlusion site. The thrombi can be removed by balloon thrombectomy which consists of a balloon inserted to the cloth. When inflating the balloon, it broadens the vessel. This procedure is often combined with a stent placed at the site. An aspiration thrombectomy uses suction to remove the cloth. Sometimes open surgery is used to remove the thrombi. The cloth could be removed by a Merci-retriever which is formed like a cork screw or a coil attaching to the cloth, or a stent retriever attaching to the thrombi and removing it. [2, pp. 100-105], [3], [21] - [24]

### 2.3.2 Treatment of Haemorrhagic Stroke

The priority for treatment of a haemorrhagic stroke is to control the bleeding. With increased bleeding comes increased pressure on the brain which is important to monitor and treat. Drugs coagulate the blood and relieve pressure on the brain. Decompressive craniectomy can be used to decrease the pressure on the brain. Depending on how large the haemorrhage is the blood might be absorbed back into the body or it can be surgically removed. There is also the possibility of surgically repairing a blood vessel.

A surgeon can place a small clamp at the base of the aneurysm to stop the blood flow. This is called surgical clipping. Coiling is a catheter based procedure where the surgeon places small detachable coils to fill the aneurysm which stops the blood flow. Surgeons can remove smaller arteriovenous malformations, AVM's, to prevent a haemorrhage. An intracranial bypass of vessels is a possible but not common solution. Another way of repairing vascular malfunctions is to use stereotactic radiosurgery. This is multiple beams of highly focused radiation that repair the vessels with minimal invasive treatment. [25]

#### Decompressive craniectomy

Decompressive craniectomy is a surgical procedure completed to minimize the intracranial pressure, ICP, created by a massive haemorrhage, primarily in the middle cerebral artery, MCA or caused by brain swelling from an ischemic stroke. A decompressive craniectomy is performed by removing the upper part of the skull and loosening the dura mater. The removal of the upper part of the skull allows the brain to swell upwards instead of pushing on other parts of the brain, causing harm. Decompressive craniectomy can decrease the risk of death with 50%. [2, pp. 105-106], [19]

## 2.4 Stroke Mimics

Stroke mimics make the assessment of stroke hard to complete with a good accuracy. Many signs of stroke mimic other conditions and many conditions mimic stroke signs. See table 2.6 for a summary of common stroke mimics. It is important to understand alternative diagnoses for stroke in order to comprehend the difficulties with stroke assessment. The most common stroke mimic is a seizure. Pregnancy can cause an inflammation in the facial nerve which may result in a facial droop. Vision deterioration or Amaurosis Fugax i.e. temporary vision loss might also be mistaken for a stroke. [26], [27]

---

Seizure	Migraine
Intoxication	Other Brain Injury
Depression	Hypoglycaemia
Amaurosis Fugax	Tumour
Spinal Injury	Previous Stroke
TIA	Encephalopathy
Pregnancy	Vision Loss

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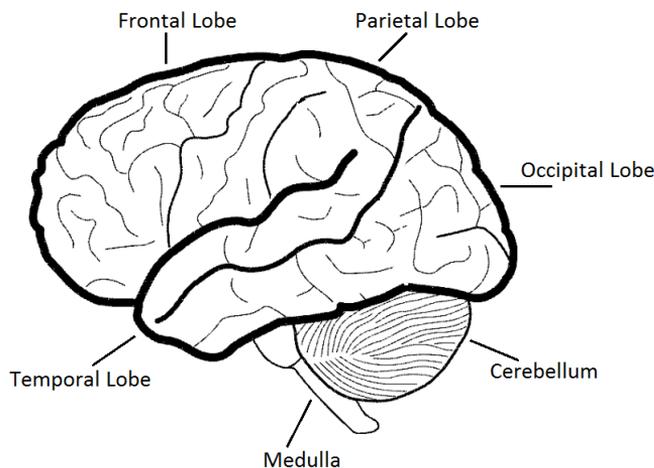
**Table 2.6:** Common stroke mimics.

## 2.5 Transient Ischemic Attack

Transient Ischemic Attack, TIA, is a malfunction of the blood flow caused by an occlusion in the brain that passes over time. TIA and stroke have equivalent symptoms but the symptoms pass during the following 24 hours, if the diagnosis is TIA. Most common is that TIA only lasts for a few minutes. Around 8000-12000 Swedish people suffer each year from TIA. TIA insinuates a higher risk, especially during the first day after an attack, to suffer a stroke. TIA and stroke use the same procedures of assessment, diagnostics and treatment. All hospitals register data from stroke but not all register data from TIA. [2, p. 12, pp. 20-53]

## 2.6 Anatomy of the Brain

The brain can be divided into functional areas describing the connection between the placement and the symptoms of a stroke. In figure 2.5 anatomical divisions of the brain are shown.



**Figure 2.5:** Overview of the brain.

The brain receives blood from two different large arteries that run along the neck. The carotid arteries run along the anterior side of the neck and the vertebral arteries run along the posterior side of the neck. Both the carotid and the vertebral arteries have a left and a right artery.

The carotid and the vertebral arteries connect and form the Circle of Willis, which is located at the base of the brain. The Circle of Willis provides large parts of the brain with oxygen and nutrition. The Circle of Willis branches out into the Anterior Cerebral Artery, ACA, the Middle Cerebral Artery, MCA and the Posterior Cerebral Artery, PCA. The MCA and the PCA both include a left and a right artery. [28]

The side that is the dominant side of the brain will determine where functional areas are placed, which in its turn affects functions reduced by a stroke. If a person

is right-handed the dominant side tend to be the left side of the brain. The left half of the brain controls the right half of the body and vice versa, resulting in a left-hemispheric stroke affecting the right side of the body.

The most common placement of an ischemic stroke is in the MCA. The MCA provides blood to the frontal, temporal and parietal lobes of the brain including the brain's deep structures, covering a substantial area of the brain. A stroke in the MCA affects the factors covered in FAST. Hemiparesis, hemi-anaesthesia, Aphasia and vision loss are all connected to a stroke in the MCA. An MCA stroke affects the upper body functions more than the lower parts of the body.

A stroke in the Anterior Cerebral Artery, ACA, results in leg weakness and sensory loss. The ACA is the least common placement of a stroke, and therefore it is also easily misdiagnosed. The ACA provides blood to the anterior medial parts of the frontal and parietal lobes.

A stroke in the PCA affects the medial occipital lobe and the inferior and medial temporal lobes. The most common effect of a PCA stroke is vision loss. If the stroke is large it may also include hemiparesis, hemi-anaesthesia, neglect and Aphasia.

Other placements of stroke are a cerebellar stroke, which affect the balance and coordination and a brainstem stroke which is rare but affect most body functions. A brain stem stroke often require life supporting measures such as respirators. [29]

If the stroke is a haemorrhagic stroke the same symptoms appear, but added to the symptoms are often headaches, neck pain and vomiting. The different placements of the stroke can result in different functional impairments and therapeutic time windows of treatment. [29], [30]

## 2.7 The Prehospital Care

There are three primary routes from which a patient suffering a suspected stroke can get in contact with the healthcare. The routes are via ambulance, referral from a primary care doctor or via the emergency room. 72% of stroke patients arrive to the hospital by ambulance. The initial assessment of a possible stroke is often completed by paramedics. No diagnosis or treatment can be carried out in the field since it can not be determined if the stroke is a haemorrhage or an ischemia, but an assessment is necessary. [2, p. 67], [12]

The paramedics can reduce the time between stroke assessments to treatment by choosing the correct transfer route. If the paramedic performing the first assessment determines that the patient is suffering a possible stroke, a stroke alarm is issued. The information from the alarm can prepare the correct unit at the hospital that a stroke patient is about to arrive. The predetermined route of efficiency in transportation and care pathways is called a stroke alarm. [12]

Vital signs, see table 2.7 are always measured in the prehospital care. Vital signs are used to complete a triage, a first classification of the level of severity of the patient's condition. Anamnesis, i.e. the medical history of the patient is also important for the initial assessment. Included in an anamnesis is for example how and where the patient was found and background information such as important allergies.

Pulse	Blood Pressure
Breathing Frequency	Temperature
Oxygen Saturation, SpO <sub>2</sub>	Carbon Dioxide, ETCO <sub>2</sub>

**Table 2.7:** Vital signs assessed in the prehospital care.

A patient's first care contact is usually the dispatchers answering the emergency phone call. The information to the dispatcher varies in quality. A person can be found by a stranger, resulting in the only known information being the gender and some short fact of what symptoms the patient is currently displaying. It might be the patient or a family member calling, who have more information. Although initial information of a stroke is received, the condition might end up not being stroke related.

The Swedish prehospital care is based on three different business models. The emergency service can be a privately owned company collaborating with the health-care, it may be the county councils that practice the prehospital services and it could also be a mix of them both. [31]

The prehospital care and the hospitalised care in Sweden are not directly connected to each other, which affect the information exchange between the two units. For example the paramedics do not have access to a patient's EPR. The prehospital and hospital care in Sweden are organised by each county council.

In England the model is based on the prehospital care being separated in its independent businesses collaborating with the in-house healthcare, called the National Health Service, NHS. Though individual businesses the prehospital care in England can be provided by the NHS, a charity or a privately owned business. There are ten individual NHS ambulance trusts in England that all conduct independent emergency services. The UK prehospital care especially prioritises a decrease of intake of false positive assessed patients. [32]

The American prehospital care include prehospital professionals who have studied one to two years, and emergency medical technicians, EMT's, who have an education of between 30-300 hours depending on background knowledge. EMT's are also present in the UK NHS healthcare. American ambulances can be operated by the local fire or police department, the fire department is the most common model to operate the prehospital care from in the USA. [33]

In Sweden all prehospital professionals are registered nurses and some might be specialised nurses. To become a nurse in Sweden the education is three years long, to specialise afterwards is at least one extra year. Altogether a specialised nurse in Sweden has trained for at least four years. [31], [34] - [35]

During the rest of the report if nothing else is mentioned, a paramedic is described by the Swedish requirements.

## 2.8 Accuracy of Stroke Assessment in the Prehospital Care

The American Stroke Association recommend an over-triage of 30% to not miss any critical patients when using stroke scales. [36]

The most frequently used stroke scale is the NIHSS scale, which was initially created in 1989, however the recommended over-triage regard all stroke scales. [37]

Over-triage also called false positives affects costs and resources whereas under-triage also referred to as false negatives is a patient safety issue. A positive result

in the following cases imply that a stroke is present, and a negative result is that a stroke is not present, see table 2.8.

		Prehospital Assessment	
		Positive	Negative
Discharge Diagnosis	Positive	TP, True Positive	FN, False Negative
	Negative	FP, False Positive	TN, True Negative

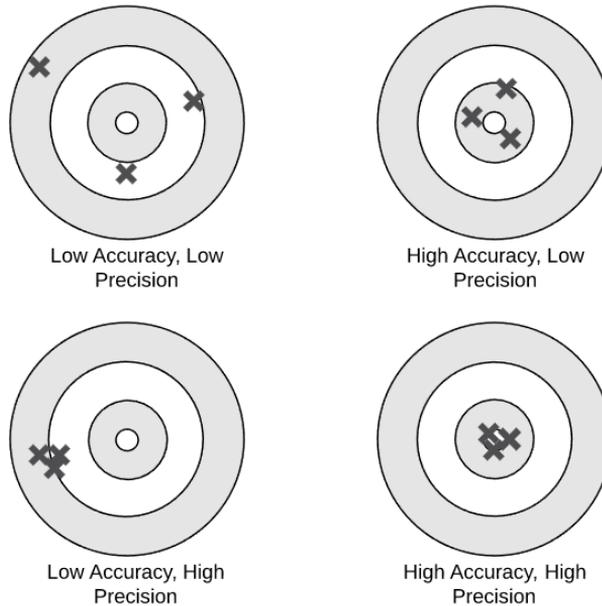
**Table 2.8:** Comparison of prehospital assessment and discharge diagnoses.

$$Sensitivity = \frac{TP}{TP + FN} \quad (2.1)$$

$$Specificity = \frac{TN}{TN + FP} \quad (2.2)$$

$$Accuracy = \frac{TP + TN}{TP + TN + FP + FN} \quad (2.3)$$

$$Precision = PPV = \frac{TP}{TP + FP} \quad (2.4)$$



**Figure 2.6:** Visualisation of differences between accuracy and precision.

**Sensitivity:** Describes the amount of patients suffering a stroke identified by the prehospital stroke scale, see table 2.8 and equation 2.1. A high sensitivity is important when handling life threatening conditions. Sensitivity is used if it is important to

identify all strokes but some over-triage is accepted.

**Specificity:** Describes the amount of healthy people identified by the prehospital stroke scale, see equation 2.2 and table 2.8. A high specificity is important when there is a need of being certain a patient is suffering a condition, for example when an otherwise life-threatening treatment should be induced.

**Accuracy:** Describes the amount of correctly assessed patients by the prehospital test compared to all assessed patients, see equation 2.3, table 2.8 and figure 2.6.

**Positive predictive test:** Describes how precise a stroke scale is at determining a stroke, see equation 2.4, table 2.8 and figure 2.6. PPV describes the prehospital proportion of positively assessed patients that actually suffered a stroke. PPV is the same as the precision.

It is mathematically possible to achieve both a high sensitivity and specificity. However in reality the choice usually has to be made between which out of the two is most important. It is a choice between over- or under-triage where under-triage is seen to have a worse outcome for the patients therefore the priority is often on achieving a good sensitivity rather than specificity.

Several studies covering years of data collection have allowed the analysis of prehospital stroke assessment quality. Due to the long duration of gathering the data it has been hard to find data closer to this date. The most recent data was collected in 2012, but it was not published until 2017 which could be a limitation since treatment techniques have changed and the public knowledge of stroke assessment has been improved with the Act FAST campaign that launched in 2011. Four studies have been included to highlight the effect of different stroke scales used. The data of four studies concerned has been summarised in table 2.9. The four studies are completed in Philadelphia, Long Island, London and Heidelberg. [7] - [10]

\* The proportion of strokes, see table 2.9 are calculated as  $(TP+FN)/\#$  of participants.

	Philadelphia	Long Island	London	Heidelberg
Years	2009-2012	2009-2011	2010-2011	2007-2010
Duration	38 months	24 months	15 months	34 months
Scale used	NIHSS	NIHSS	FAST	FAST
# of Participants	709	310	295	689
TP	230	56	171	170
TN	206	217	15	333
FP	103	9	103	156
FN	170	28	6	30
Sensitivity	57.5%	50.0%	96.6%	85%
Specificity	66.7%	96.0%	12.7%	68%
Accuracy	56.5%	88.1%	63.1%	73.0%
Precision/PPV	69.1%	86.2%	62.4%	52.1%
Prop. of Strokes *	56.4%	27.1%	60.0%	29.0%

**Table 2.9:** Comparison of four different studies of prehospital stroke assessment.

Two of the studies include stroke assessment by the NIHSS and two by FAST. All studies include both ALS and BLS ambulances which is common in many countries but does not exist in Sweden. An Advance Life Support, ALS, ambulance can be compared to regular ambulances used in Sweden and a Basic Life Support, BLS, ambulance is operated by EMT's and can be compared to a more basic vehicle with the single aim of transferring ill people to care facilities. The final diagnosis was in all studies based on TIA/stroke and non-strokes, since it is impossible to separate a TIA from a stroke in a prehospital setting. [7] - [10]

The Philadelphia study covered 709 cases of suspected strokes assessed with the NIHSS. Out of 400 discharge diagnoses of stroke 230 were found by the EMS crew, giving a positive predictive value of 69.1% and a sensitivity of 57.5%, determined in a large metropolitan area. The overall stroke ratio was 56.4%. The overall ratio is the highest out of the three studies and it is because the study was focused solely on stroke patients. No missing data had to be handled since the study was not a retrospective study, which may also have increased the ratio. The Philadelphia study was the only study that was carried out in real time. [7]

The Long Island study includes three different hospitals in Brooklyn, Long Island and Kings County and the study covers 310 patients. The study was a retrospective study including all patients arriving at the hospital by ambulance with a suspected stroke. The Long Island study was based in urban, underprivileged parts of the cities. 22% of the population are living below the poverty line in these cities, which implies no health-insurance, affecting the treatment and help received. [8]

The retrospective study in London covered 295 patients with suspected stroke assessed by paramedics using FAST. All 295 patients included had been assessed with FAST in the ambulance and later on given a definite diagnosis by a senior stroke consultant at the hospital. Applying FAST only for suspected strokes and not all neurological symptoms increased the sensitivity in this study. [9]

The study completed in Heidelberg, Germany included 689 suspected central nervous system disorder patients assessed using FAST. The study was a retrospective study on patients assessed by both paramedics and EMT's. This study did not concern FAST assessment completed in a prehospital environment due to lack of standardised reporting. Instead the outcome of FAST has been retrospectively calculated by the stroke scales used in the emergency room, ER. The layout of the study may have introduced an uncertainty of the result as paramedics and EMT's are not as good at determining these signs as the doctors in the ER are. [10]

A smaller trial has also been carried out in Håssleholm, as a pilot study testing the accuracy of the preHAST stroke scale implemented in the prehospital assessment. 69 patients were assessed using preHAST, 26 of the patients had a final diagnosis of stroke and 43 patients were diagnosed with non-stroke symptoms. Out of the 26 patients with a discharge diagnosis of stroke all were found by using preHAST, the sensitivity was 100%. Out of the 43 non-stroke patients, 17 were found by preHAST and 26 patients were assessed as stroke patients in the prehospital assessment but later determined as false positives. The specificity was 40%, but increased with higher scores in preHAST. The PPV was 100%, accuracy was 62.3% and the proportion of strokes was 37.7%. [17]

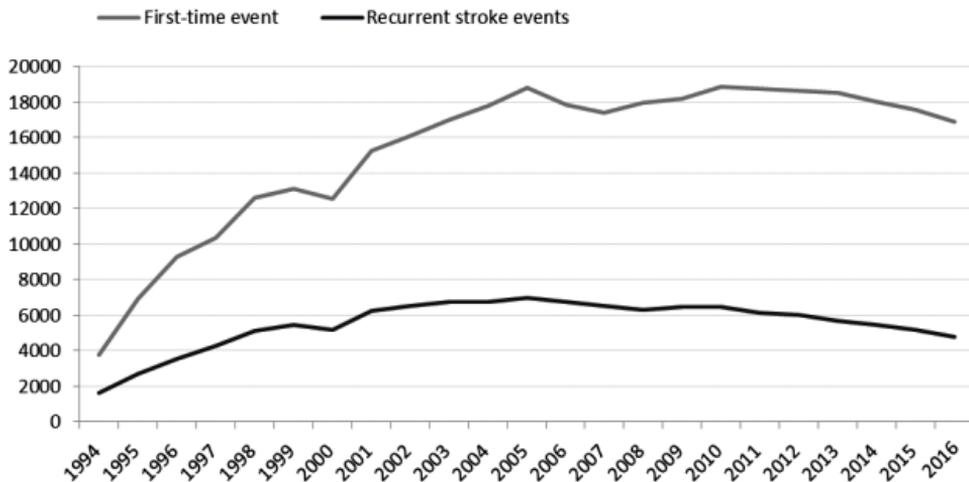
Since NIHSS and preHAST are score based scales including many parameters they are general screening methods as well as tools to determine the severity of stroke, whereas FAST can only screen for large vessel occlusion. The main findings in the studies are large numbers of over-triage and the variability of symptoms detected by different stroke scales.

FAST has a much higher sensitivity than NIHSS in all studies compared, but it can not be determined that FAST is better at assessing stroke since all studies differ in layout. NIHSS screens for general strokes which also introduces more parameters to be assessed and thereby more parameters that may be affected by a symptom mimicking or displaying a stroke. A patient receiving care from prehospital professionals usually displays more severe and clear symptoms than patient's receiving help from other care pathways. Since the general population is familiar with FAST the suspected strokes called in to the first responders are often linked to these symptoms when a family member or patient suspects stroke. The factors in FAST largely affect a person's ability to interact normally which usually is detected by a relative, whereas other factors in the NIHSS are more subtle and not as tightly linked to stroke signs known by the general population.

All four studies included ALS and BLS ambulances as well as EMT's which may have reduced the scales results. The preHAST study did not include ALS or BLS ambulances or EMT's. The preHAST study showed better results in many aspects compared to the four studies completed abroad. It may be due to the small sample size of the preHAST study or the new stroke scale but it may also be due to the higher educated paramedics and better resources in the Swedish prehospital care.

## 2.9 The Swedish Stroke Register

Riksstroke, the Swedish Stroke Register, is a request from the Swedish social board among with Sweden's municipalities and county councils. Riksstroke's aim is to collect data from patients suffering a stroke or TIA in all parts of Sweden to achieve a high quality care, regardless of location, gender or age. Figure 2.7 shows the cumulative number of stroke events registered in Riksstroke from 1994 to 2016.



**Figure 2.7:** Number of stroke events registered in Riksstroke 1994-2016.

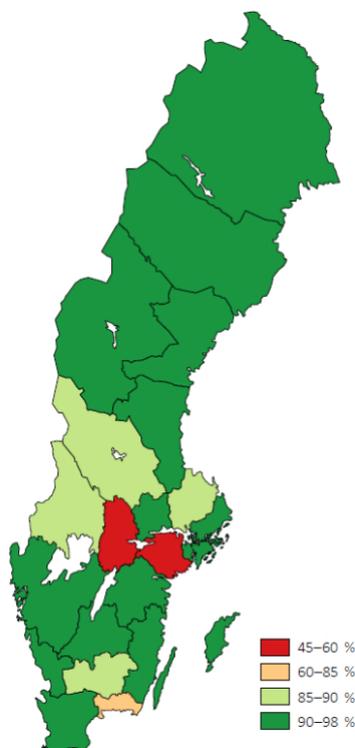
The data registered in Riksstroke is collected at three stages, at the time of the stroke, three months after and a year on. Data is collected by interviewing the patient but also from the EPR. The data include all patients with a final diagnosis of stroke or TIA, it does not include conditions initially assessed as stroke and later determined to be something else. [2]

There are 72 hospitals in Sweden that care for stroke patients. All 72 hospitals report to Riksstroke. [2, p. 56]

There has been a slight decrease in reported strokes to Riksstroke during the last few years. The decrease indicates, according to Riksstroke, that the primary and secondary preventions of stroke are working, as for example the FAST-campaign. The amount of registered events has decreased with 1% each year during the last ten years even though the population of elderly has increased within the same years. The ratio of reported strokes has varied slightly over the years, which can be accountable for some, but not all the decrease. The result implies that there is a significant but small decrease in amount of strokes. Riksstroke discusses the possibility that less patients seek help as an unlikely reason for the decrease. [2, p. 56]

The care given and the methods for registration used differ a lot between different hospitals in Sweden, which makes the data harder to interpret. [2, pp. 13, 56-58]

Many hospitals treat stroke patients at other units than a stroke unit during the first critical 24 hours of care. The restricted access to receive qualified stroke care at a stroke unit or an ICU is the area most in need of improvement identified by Riksstroke. One in five patients do not have access to stroke care at a stroke unit, see figure 2.8.



**Figure 2.8:** Percentage of patients that receive care at a Stroke Unit.

The reason to the restricted stroke care is lack of space, that older patients are less prioritised and different routines between hospitals. Riksstroke recommends all users to use the NIHSS for better compliance and interoperability between different units and hospitals. [2, pp. 56-58, pp. 72-77]

The number of treatments with reperfusion therapy continues to increase, but the possibility to receive this treatment is not equal throughout the country. The increase of reperfusion is related to the increased number of stroke alarms sent from the prehospital care as well as a shorter time between detection of stroke to care. The increase in reperfusion therapy is also affected by new strong evidence of the positive effect of reperfusion therapy and the innovation of new catheters for thrombectomy. This has resulted in reperfusion therapy increasing in use with 28% last year, now also available for patients above 80 years. [2, pp. 67-74, pp. 82-106]

## 2.10 The Digitalization of Healthcare

The Swedish, European and worldwide healthcare is experiencing a digitalization. The digitalization aims to achieve more efficient work processes, safer patient flows, improve the possibilities for follow ups and create a patient-centred care. An aging population and a fast technical development create higher demands on the information flow and the accessibility of the healthcare. Healthcare should be made more flexible, equal, efficient and integrated. There is a demand on the correct information at the right time. [38]

### E-health

Vision 2025 is a vision set by the Swedish government, municipalities and county councils which aims to improve e-health use and solutions in Sweden. According to the report describing Vision 2025, healthcare should be evidence-based, safe, provided in time, distributed fairly, patient-oriented and cost-effective something that e-health can improve. E-health enables the healthcare to become more patient focused and it can create increased efficiency leading to a sustainable healthcare. E-health provides accessibility, usability and participation. E-health should favour all users and lead to a better work environment. To achieve the vision laws, terminology and standards will need to be revised. E-health is a part of the digitalization of healthcare. [39]

Vision 2025:

*“By 2025, Sweden shall be the best in the world to use the potential of digitalization and e-health to achieve good and equal health and well-being as well as develop and strengthen resources for increased independence and participation in the society.”* [39]

Information and communication technology, ICT, systems aim to create unified communications and integration of telecommunication and computers, including for example the internet and cell phones. In healthcare ICT is often described as the term e-health. [40]

## Telemedicine

Telemedicine is video consultation by a remote doctor. Telemedicine is implemented in most hospitals, but data transfer through 3G and 4G is limiting the use of telemedicine in the prehospital care. Tele-consultation in the prehospital care is currently being developed and tested. Within the last few years there has been evolving techniques in data-transfer, but several limitations remain regarding the transfer of data. For example the coverage is limited in some geographical areas, especially when the ambulance is moving and a high consumption of data in an area might make the transfer slow down or stop. [30]

## IoT

The Internet of Things, IoT, is the integration of physical devices with network connectivity, software, sensors and electronics to enable connections and exchange of data between objects. The transfer of data between the participating objects should flow freely without interruptions. IoT in healthcare can create a more personalised care and reduce costs as well as gather and share information easier. IoT is also seen as a factor that can create "The right care for the right person at the right time". [41]

## 2.11 Legal Restrictions

A challenging part of developing an extended portfolio of e-health solutions are legal and regulatory aspects. The legal restrictions include privacy, confidentiality, liability and data-protection. As in many new and upcoming areas the development of new techniques may occur before legal updates are made. [42]

Filming a patient, gathering personal data and creating a medical device, require legal compliance. Examples of legislation of importance are the Camera Surveillance Act, the Patient Safety Act and the Medical Device Regulation, MDR.

The Patient Data Act controls the patient data collected in Sweden. The Patient Data Act enables professionals to access information from Electronic Patient Records, EPR, digitally, which ensures a share of locally stored information throughout the entire country. The Patient Data Act creates more autonomy for the patient by determining which data is shared and who has been given access to the medical record. [42]

The Medical Device Regulation, MDR, introduced new legal classifications on software included in a medical device. For research purposes, which this system will have to pass for validation, an informed consent is needed either by the patient or his or her legal guardian. To conduct the research an ethical approval is needed from the Swedish social board, if the research is to be conducted at Swedish hospitals. The General Data Protection Regulation, GDPR, is EU's new framework for standardised data protection laws. This framework will affect the way data can be handled and used. GDPR changes the way sensitive and personal data can be processed, stored, deleted and disclosed. [43]

The laws affecting IT-systems within the Swedish healthcare are primarily the Health Care Act, the Occupational Health Act, the Press Freedom, the Secrecy Act, the Patient Law Act, the Social Services Act, the Health Register Act, the Ordinance on the Processing of Personal Data in Social Services and the Personal Information Act. [44]

## 2.12 Ortivus

The thesis is a request from Ortivus, a leading supplier of mobile solutions for modern emergency medical care. Ortivus focuses on decision support systems and developing mobile monitoring and communication solutions in Sweden and in Great Britain. [45]

Ortivus is already well-established in the prehospital care and hold many important contacts used in the research for this thesis. The aim of the thesis is a mixture of requests from users for video support in ambulances and market openings discovered by Ortivus. Ortivus strives for innovative, user-friendly, safe and operationally critical systems for monitoring, diagnostics and reporting in the prehospital care.

Stroke was determined to be a good area to research since the effects on telemedicine solutions regarding stroke have been thoroughly studied. Since stroke is one of the most common conditions in Sweden there is interest in all solutions resulting in a better outcome.

Ortivus have two products on the market, MobiMed, which is an EPR solution and CoroNet which is a monitoring system. MobiMed supports communication via 3G, 4G, GPRS, TETRA and satellite. Ortivus product MobiMed, to which the suggested system could be a complement, is classed as a class IIb medical device according to the MDR. A class IIb device is non-invasive but measures vital signs and the product can introduce a high risk to the patient if not working as intended. For class IIb and III, which are the highest classed devices a notified body needs to approve the device. Ortivus also comply with three different ISO-standards and the products are CE-marked. [45]

## 2.13 Limitations

Since many articles regarding the American healthcare have been found and used, limitations have been made according to markets. The thesis concentrates on the Swedish healthcare, if the Swedish and American healthcare differs in any way it will be mentioned. Some facts will include data from the UK to cover all markets that Ortivus are involved with. Inspiration will come from all over the world but the discussions regarding implementation and legal aspects will be aiming at the Swedish healthcare.

The collection of data was limited for multiple reasons. In order to create a report including many aspects, experts from different areas had to be interviewed. The aim was to find four experts within healthcare and one expert in video analysis. This may have introduced a bias affected by the people chosen to interview. All information gathered through interviews has been compared with literature findings in order to strengthen conclusions and reduce bias.

The method describes the approach of gathering data as well as methods used for structuring and analysing data to generate results.

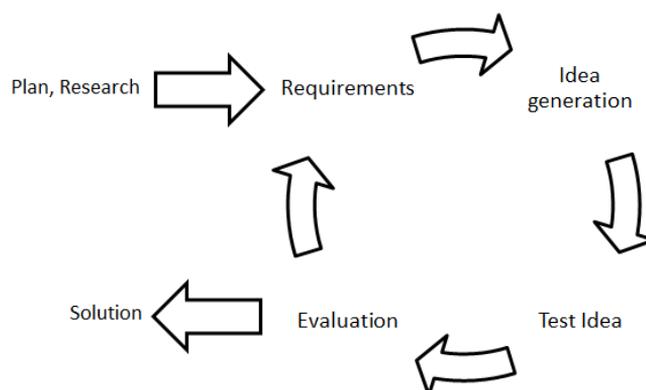
To achieve the aim, the workflow of the project was divided into three areas.

- To collect data.
- To analyse and interpret data.
- To create specifications of a conceptual system.

The collection of data created by interviews, observations and literature studies is covered in section 3.1 and data analysis methods are further discussed in section 3.2. The methodologies for the specifications generated are thoroughly described and discussed in section 3.3.

## Scientific Approach

To include more knowledge along the way an iterative process was followed, see figure 3.1.



**Figure 3.1:** An iterative scientific approach.

Some official documents such as standards and legislations have been interpreted to comply with the demands from the market and the government.

To examine and analyse the collected data it has been compared to existing theories found in literature. Existing theories were not easy to find since the topic is very limited. Instead inspiration from relating areas found in literature created the basis of current solution and broadened the data included in the thesis.

## 3.1 Data Collection

Qualitative interviews and semi-direct observations were completed during the first half of the time-span for the thesis. The literature studies have been ongoing during the entire process.

### Case Study

A case study is a detailed examination of a subject. The case study was completed to investigate if the idea could be implemented in reality. The case study is built on interviews, observations and the literature study.

#### 3.1.1 Literature Study

To determine the state of the art, statistics of prehospital stroke assessment and video analysis, the project began as a literature study. The project was iterated and updated many times when new information was gathered.

A literature study was completed because the area is novel, many solutions had to be found within other areas and applied in the researched area. A literature study allowed the validation of some chosen factors included in the suggested system although the factors had been implemented for a different use when validated. The literature study gathered a lot of data which was used to construct the layout of the system as well as for understanding of the prehospital care, stroke assessment and video analysis.

The result from the literature study has been used to strengthen conclusions drawn by the author or ideas from the interviews. The suggested system is based on state of the art stroke scales, quantitative measures, software systems and hardware functions.

An important and big part of the literature study included research of different stroke scales. Since many stroke scales are used it has been important to understand what differentiates the scales and why some scales are more widely used than others. It was also important to find the most used scales in Sweden and to understand what the different measures gave for information to the clinician.

It was not possible to adjust the system to comply with all stakeholders desires, therefore the result from the interviews and observations was compared to literature to achieve a compromise that could work in reality.

#### 3.1.2 Interviews

Six semi-structured interviews have been carried out during this thesis. All interviews were completed in face-to-face meetings. The interviews were arranged to get an insight to as many stakeholders' perspectives as possible. [46, pp. 228-238]

Semi-structured interviews are set up the same for all participating parts. Open questions are constructed to not influence the person being interviewed, however the questions have varied depending on the interviewees area of expertise. To achieve a

representative selection of interviewees the author had beforehand concluded who the primary, secondary and tertiary users would be.

The interviews and the observation were completed at different Swedish hospitals to create a geographical fluctuation of the participants. A geographical fluctuation was important in order to include the variations in stroke assessment. To achieve a representative selection is critical in order to get good and reliable information from an interview. [47, pp. 42-44]

Some interviewees were included in the primary user group, but some were not. It is sought to be a good idea not only include the primary users when collecting the data, to get an understanding of all users. [47, pp. 42-44]

The interviewees were given cases and multiple ideas as suggestions if they could not themselves think of an answer to a question. This was a way to increase the outcome data from the interviews still using relatively few participants. Introducing suggestions might have biased the interview but this was only done if the answer would have been left blank otherwise. The disadvantages were seen to be smaller than the positive effects with doing this.

Since interviews with different stakeholders were completed in different parts of Sweden the variability in stroke care and stroke assessment might have influenced the outcome. This could have affected what the interviewees answered to different questions. The questions asked are shown in Appendix A.

All interviewees were randomly and independently chosen to provide an overview of prehospital stroke assessment. Below is a short description of why the interviewees were chosen.

Bengt-Arne Sjöqvist is professor of practice of Health Informatics at Chalmers University and founder of Prehospital ICT Arena and he was chosen because of his long-term interest and knowledge about the prehospital care and innovation within it. Two paramedics, Magnus Carlsson and Fredrik Wretman were interviewed about their end-user knowledge in the emergency care in Västerås. Elisabeth Rooth is a Chief Physician and the Process Owner of Stroke at the hospital in Danderyd in Stockholm. She was chosen from a set of doctors due to her large expertise within the subject and her will to improve the current stroke assessment. Rooth works as an on-call doctor and is therefore well informed both of the prehospital assessment as well as the hospital route of treatment and assessment. Magnus Esbjörnsson works at the hospital in Hässleholm. He is the Head of Medicine in Neurology and Internal Medicine. Esbjörnsson is together with the paramedic Gunnar Andberg the creator of the preHAST stroke scale used by paramedics in Skåne and Västergötland. Esbjörnsson led the trial of implementing a video-link between the ambulance and an on-call stroke doctor, which was the first ever used video ambulance in Sweden. Magnus Esbjörnsson is also a part of the internal regional on-call stroke line in Skåne. Klas Bengtsson, a technical seller of sensors, vision and ID was also consulted to strengthen the hypothesis that a system could be created with current technology. He was asked about other similar methods in other markets or for other purposes to widen the scope of the project. The result of this interview is presented in Section 4.1.1.

### 3.1.3 Observations

The layout of the observations was according to semi-direct observations on the field, described in Appendix B [46, pp. 247-259].

Due to the busy work as a paramedic, the small space in the ambulance and the

small chance of observing a real stroke assessment, a simulated stroke assessment was completed instead of direct observations in the field. Being observed might change the interaction from how a person would normally interact. [47, p. 52]

Privacy and respect were key reasons as to why the author felt that she could not do an observation with a real patient.

The observations involved simulations of how stroke scale assessments are completed in the ambulance. Simulating a stroke assessment created more detailed information, by giving the author a chance of asking questions while completing the assessment. It also gave the user a chance to explain what he or she was doing while completing the stroke assessment.

The inside of an ambulance was observed to understand the area, other devices used and to create an understanding of where the placement of the cameras, if placed inside the ambulance was possible. The author also observed ambulance crews preparing to go out for a mission. The observations of stroke assessment were performed in two independent observations of the paramedics interviewed in the ambulance care in Västerås. The author has also used the simulated stroke assessments recorded and used in the demo for further observations.

Observations were completed to include multiple analyses on the qualitative data to determine if the information all led to the same conclusion, this is triangulation. [46, p. 225]

Another important reason was to experience the current implementation and issues at first hand. This was a way to approach a human-centred design. A human-centred design attempts to get insight to the problem in order to create specifications of services that the product should include. In this way design-ideas can be generated and discussed. The process of creating a human-centred design describes how the iterative work during the entire thesis has been conducted. [47, pp. 9-11]

## Survey Method Motivation

The two survey methods, interviews and observations, were combined with literature research in order to fulfil triangulation [46, p. 225].

Triangulation was achieved in various ways, for example by using three different data gathering techniques, including multiple interviewees, at different times and places, as well as multiple stakeholders interpreting the data.

The observations and interviews were performed to create insight to the problem and how the solution should be created. The interviews established a vision of what to include in the system. The observations generated insight of the limitations that the product has to overcome.

## 3.2 Data Analysis

The methods described below have been used to analyse and structure the gathered data.

### 3.2.1 Mapping of Users

In a wider sense the mapping of stakeholders can be described. A stakeholder is anyone that will be affected by the system or that have direct or indirect influence on the system requirements. Affecting one part of the stroke chain will have consequences for many different parts of the chain. [46, pp. 333-334]

The users are primary, secondary and tertiary users. Primary users are frequent hands-on users of the system, secondary users are users that occasionally use the system or that are using the system through an intermediary. Tertiary users are users that are affected by the use of the product or that are involved with the purchase of the system. [47, p. 43], [46, p. 333]

Stakeholders, primary, secondary and tertiary users were identified through literature studies and interviews. It was important to derive the stakeholders and users of the system in order to understand functions needed and to create a user-centred design. Different functions in the suggested solution are derived from different users' perspectives. Some users may require a function that other users do not.

### 3.2.2 Brainstorming

Brainstorming is used to generate many ideas in a small amount of time. All ideas generated, whether good or bad are written down. Brainstorming was completed using the mind mapping method and by writing down ideas on separate notes and arranging the notes into corresponding themes, also called an affinity diagram. Brainstorming was performed to structure the data collected through the three methodologies earlier described. It was important to structure the data since so much information had been collected. [47, pp. 94-95]

The brainstorming session that created an affinity diagram resulted in many alternative ways to develop the system and ideas to arrange and rearrange in order to combine into the best solution. To generate many ideas when working alone may be difficult, therefore many stakeholders at Ortivus have been helpful in questioning and encouraging ideas, ultimately improving the outcome.

The mind mapping method includes the system in the middle, branching out into different solutions. The mind mapping method was used to generate ideas of technical solutions and the brainstorming resulting in an affinity diagram was used to determine users' demands.

### 3.2.3 Affinity Diagram

In order to group ideas from the brainstorming method using separate notes, an affinity diagram was created. An affinity diagram is a qualitative data analyse which divides the data into more and less important divisions, themes. An affinity diagram aims to organise individual data into groups forming structures and themes. Constructing an affinity diagram is a good way of an initial analyse of qualitative data. [46, pp. 285-289]

The affinity diagram structured the data and visualised demands from different stakeholders. The literature study gathered most of the data used for creating themes.

### 3.2.4 Functions

To derive requirement functions has been an important step in describing what the system can do. The functions were primarily derived from the themes in the affinity diagram describing user demands on the system. The functions have created a base for the entire system specification.

The functions are listed as demands on the system. All functions should be included in the final system, but some are hard to express in the suggested system because it is a conceptual system. All derived functions have been determined to be

essential for the final system. Derived are all specified essential functions resulting in a novel stroke assessment system.

The derived functions cover an overall understanding of:

- The placement of hardware
- The primary user
- The transfer of data
- How the assessment is completed
- How the system is beneficial
- What the system offers
- When the user can control the system
- How information is visualised by the system
- How the system is included in the prehospital care

### 3.2.5 Use Case

A use case is a list of actions or event steps that defines interactions between an actor and a system to achieve a goal. All actors must be decision making but they do not have to be human. A use case is a type of written requirement specification. Use cases are user-centred, developing a use case can be a step towards a user-centred design.

The aim of a use case is to create easier communication links between stakeholders, developers and designers and to increase the user experience. A use case captures requirements of a software application. The use case describes the actions a user goes through to complete a specific goal when using the software system. All possible choices that the user might make should be taken into consideration. A use case captures what the system does, not how.

A use case is often represented as a text description and a Unified Modelling Language, UML, diagram displaying the case. Two factors of dependencies can be included in the UML diagram, the factors are *include* and *extend*. [46, pp. 370-371]

*Include* is used if the action depends on another action in order to be completed. The *include* action can not stand alone, it is used to include factors that appear in many cases, to avoid duplicated code.

*Extend* describes optional actions, which may be required depending on the path of the use case. It is additional behaviour to the standard solution. An extended action is a build-on to a foundation. The extended action can stand on its own.

The text description of the use case contains:

- A title of the use case
- The primary actor of the use case
- The scope of the use case
- A brief description of the use case
- All stakeholders affected by the use case

The use case created was derived to describe the system in multiple ways and thereby ease the understanding of the system. The demo created will focus on facial feature detection, therefore the use case created focuses on the same issue.

The use case structured thoughts as well as determined how the suggested system should work. It is important to gather all demands and include them in the system. By doing so, contradictory functions may appear and can be altered for. It creates an overall view of the intended system layout.

### 3.3 Specifications

The product specifications could be derived after sorting and analysing the collected data and comments from stroke experts, paramedics and other important stakeholders.

The result presents an overview of the technical demands on the system, the placement of modules and quantitative measurements included to assess stroke with video analysis. The specifications of the system are thoroughly described in the sections below.

#### 3.3.1 The Conceptual System

A conceptual system is built on ideas and concepts. A conceptual model is used to describe how the system is organised and how the user can interact with the system. It is important to support the parts of the product that may cause the most problems or errors or a function that is critical when used.

A conceptual model is created in order to make sure all users understand what the system is able to create. This is an iterative process used to repeatedly test multiple choices of functions and determine the best ones. The best conceptual models are intuitive. When designing a system a good way of creating an intuitive conceptual model is to base choices on other well-established conceptual models. Creating a conceptual system is a step in creating a user-centred design. [46, pp. 40-43, pp. 403-407]

The conceptual system described in the thesis is referred to as the suggested system. The suggested system is based on interactions currently completed when using the EPR and it mimics the current stroke scales completed by paramedics. The suggested system is mainly based on the functional requirements, the result from the brainstorming activities and the current state of the art in the stroke assessment area.

The conceptual system broadened the understanding of how the system should work. The conceptual system is an overall explanation of what functions, hardware and software that have been of importance in creating the system.

The conceptual system is supposed to create an overview of all factors included in the system. It is more specified than the functions and should cover a short description of the entire system.

#### 3.3.2 Product Specifications

The product specifications are derived from the mind map created by brainstorming. The product specifications for the prehospital care and the in-house hospitalised care are described and visualised to enhance the information of what is included in the suggested system and where the different compounds are placed. The product specification is in this case an overview of the suggested system. It does not contain details of which hardware or software to use. Instead it covers important functions of the hardware and software.

The product specifications also include a work flow of the suggested system. The work flow was included to visualise how the work flow will change after implementing the suggested system but also to create a deeper understanding of how the suggested system may be used. The work flow has been derived from the work flow described in the interview with the paramedics as well as from the demands on the suggested system.

### 3.3.3 Video Analysis

To understand the current market on smart cameras and video analysis solutions Klas Bengtsson from Metric Industrial was interviewed. The interview was mainly used to verify the results found in completed trials within the healthcare area, as well as learning about implementations in other areas that could be compared to the suggested system.

It is important to understand that there are no right or wrong algorithms when creating the software. Different algorithms will produce different results.

The video analysis has been divided into a summary of the literature findings covering the area, see Section 4.1.1 and the specifications generated concerning the suggested system, see Section 4.3.3. The sections are very important in understanding the limitations and possibilities with including video analysis.

The video analysis includes discussions on feature detection, standardised facial landmarks, segmentation, feature extraction, classification algorithms and verification. The sections cover the use of Artificial Intelligence, AI, as well as a discussion on whether to use AI or statistical models in the suggested system.

Three alternative ways of creating the algorithms for the suggested solution have been compared and discussed during the interview. One is to use a smart camera, another to build the software tool from scratch and a third to use prewritten code. To use a smart camera or prewritten code will allow a quicker market entry. However it will also be a system limited by the functions in the chosen solution and the system will depend on another company. To outsource a part of a product can spread risks, but at the same time final costs may be larger than creating the solution in-house.

The three choices are discussed from different angles depending on the solutions found on the market and from trials studied. However the result from the video analysis mainly covers found factors creating a facial feature detection algorithm.

### 3.3.4 Quantitative Measurements

To find measurements of stroke assessment that could be quantified has been crucial. To find the measurements all survey methods and literature studies were included. The result of the survey methods and literature studies is presented in Section 4.1.1 and the result creating specifications of the suggested system are presented in Section 4.3.4.

Some parameters found were more reliable and had been verified in other studies. Some factors are novel and should be further researched before used.

The search for quantitative measurements of stroke has been important in order to ensure that there are measurements determining stroke that could be assessed by a system. The result of finding many quantitative factors for stroke assessment has been the single reason that this report could be created.

The quantitative measurements derived focus on measurements which include video analysis and that does not require more sensors to analyse the condition. Some

more novel measurements that require additional sensors have also been mentioned to broaden the current stroke assessment ideas and to visualise that more factors of stroke assessment are present.

To generate quantitative measurements some requirements were set:

- Include currently assessed stroke parameters
- No external sensors required
- Measurement completed inside an ambulance
- Create multiple answers from one measurement

The requirement of the parameter being a currently assessed stroke parameter was included to use existing knowledge. By including prior knowledge the parameter could be validated and the implementation of the new assessment would be easier when some aspects were familiar.

No sensors required was a requirement initially set by the primary users. Sensors would hinder the workflow and increase the knowledge needed to complete the assessment. It would also increase the time.

That the measurements are possible to carry out inside an ambulance has been determined as a demand after the placement of the cameras was determined. If the measurements can not be conducted inside the ambulance no time is saved.

To achieve multiple answers from one assessment is crucial. It is made possible by using more than one camera as well as including the paramedic and an on-call doctor in the assessment.

All four requirements were generated to reduce the time and increase the efficiency. The requirements were determined to not make the assessment more complex to execute and to not hinder the work flow. The best chosen measurements are parameters that can be assessed even if the patient has cognitive reductions. The assessment must not affect the patient in a negative way by for example prolonging the time, distracting the paramedics or resulting in a faulty assessment.

### 3.3.5 Demo

In order to conclude and visualise what the thesis has resulted in a prototype demo was created. The demo created is not interactive but it visualises a flow between parts included in the system to give the user an understanding of what is included.

The demo transforms initial requirements set by the literature, interviews and observations into a visual system. The demo describes, from one video-angle, what users will be able to do with the finished product and how the interactions with the product will take place. The demo should gather and combine the found data. It will structure the solution, improve the outcome and give a better tool to describe the solution to the stakeholders.

The demo is based on one of three recorded simulated stroke assessments from a non-published research trial aiming to assess the possibilities of including telemedicine in the Swedish prehospital care. The simulated videos include two professional paramedics and a patient, which is a neurologist acting as a patient according to a script given before the simulation started. The three recordings included three different actors simulating patients with diverse stroke severity. The simulation chosen to derive the demo from is the least severe patient. This meant that the patient is able to answer questions and follow instructions on a cognitive level but

on a physical level the patient experiences difficulties performing some instructions. The author has the permission to use the videos and images in the videos solely for use in the report.

The videos of simulated stroke assessment were recorded from three angles each in three patients. The angles were a leg view, an arm view and a facial view. The angle chosen to derive the demo from was the facial view. The choice was based on software available on the market for free testing and an easy visualisation of the video as still images for this report. For leg and arm assessment motion is needed to track the path. The path could have been visualised for example by leaving a trail of motion, but the face was seen to enable a clearer visualisation in a still image. The chosen software could also analyse many different parameters from a facial video, for example gaze-tracking, facial detection, emotion analysis and gender analysis.

To create the demo Visage Technologies' software development kit called Visage|SDK was used for Facial Feature Detection as well as Gaze Tracking. The software focuses on facial detection and analysis, the trial demo version of the SDK was used to create the images in the report. The template of the EPR used in the demo is a specialised version of the MobiMed EPR.

The demo is based on current layouts and functions in Ortivus EPR implemented and used in the south west trusts in England. Alterations and expanded functions have been included in order to visualise the suggested system. Some pathways for extended assessments and guidance are present in the English EPR, for example guidance for cardiac arrest. There is currently no guideline implemented in the English EPR's on extensive stroke assessment, therefore alterations had to be made.

The author has Visage Technologies written consent to use the images created by their demo solely for use in this report. Appendix C describes the Visage Technologies Software Development Kit.

The result describes the outcome of the analysed data gathered in survey methods as well as the generated data from methods used to derive the system.

To achieve the aim, the workflow of the project was divided into three areas.

- To collect data.
- To analyse and interpret data.
- To create specifications of a conceptual system.

The collected data from interviews, observations and literature studies is presented in section 4.1 and the data analysis is discussed in section 4.2. The specifications created by the data are thoroughly described and discussed in section 4.3.

## 4.1 Data Collection

The data creating the report is divided into a literature study, interviews and observations which are summarised in the sections below.

### 4.1.1 Literature Study

The result from the literature study is divided in to a summary of novel solutions of prehospital assessments as well as video analysis solutions.

#### Prehospital Assessment

The sections below include novel inventions and the state of the art. State of the art describes the most recent ideas, research and development of products or features on the market. Some of the newest research areas are telestroke, comprehensive stroke centres, CT included in ambulances and image analysis to monitor patients.

#### Telestroke

The state of the art stroke assessment is based on telemedicine through remote video consultation by a stroke expert, also called telestroke. The overall aim with telestroke is to decrease the time from symptom onset until treatment in order to ensure a better and more standardised stroke assessment for the population. A common factor in many telemedicine trials is that they are focused on stroke. This is because stroke

is one of the most costly conditions and that optimizing time is essential for the outcome. [42], [48] - [51]

The implementation of telestroke is increasing in studies relating to the prehospital care. Telestroke was initially seen as beneficial for rural areas but has later been thought to decrease DNT, door-to-needle time. [48], [49]

A Finnish study of telestroke's effect on DNT concluded that the DNT is optimised more efficiently by a determined workflow, i.e. a stroke alarm, than by including telemedicine. The derived reason creating the result was the factor of support in transferring the patient, a routine path could be followed, which made the process more rapid. A standardised way of caring for a suspected stroke may decrease the DNT because the results of the prehospital assessment could be reused by users along the line of care. [49]

PrehospIT is a national collaboration project driven by Prehospital ICT Arena in Sweden. Their aim is to create efficient systems to improve ICT and e-health solutions in the prehospital care by creating national standards and technical interoperability. As a derivative of PrehospIT, ViPHS – Video Support in the PreHospital Stroke-chain was founded. ViPHS aim is to study different areas of use for video support systems in the prehospital care. ViPHS solution is based on a video consultation between the paramedics and a stroke expert with three stationary video-cameras placed in the ambulance. The cameras used in the trials were Axis cameras, including a camera for close up images, a fisheye camera for a broader image of the entire ambulance as well as a camera including a view of the patient's whole body. [50]

A project carried out in Belgium is testing the use of video consultation combined with remote diagnosis and treatment of patients with stroke in the prehospital care. The aim is to extend the capabilities of first responders, to create live interaction with remotely based doctors and equipment. The study cover problems such as data storage, network connection, transfer of data and the connection to the hospital. The ambulance used contains many sensors and possibilities for diagnosis as for example ultrasound. The ambulance is connected. Testing the system in clinical use has been concluded with a good outcome in 2017. [51]

The area of telestroke may be a good standard to base the suggested system on. Telestroke will allow a decreased level of entry between the current workflow and the suggested change described in this report. Since cameras are already installed in the ambulance when using telestroke the actual step of implementing the suggested system will be more focused on changing the mind and workflow of the healthcare professionals' than the technical layout.

## CT Ambulances

CT ambulances, also called Mobile Stroke Unit, MSU and Stroke Emergency Mobile, STEMO, have been researched and implemented for testing. [30], [52] - [53]

The MSU and the STEMO contain a CT, a point-of-care laboratory system, IoT systems and possibilities for telestroke as well as transferring of CT scans for remote interpretation. The CT ambulance is more in the form of a small truck than an ambulance. The CT ambulance is a test to improve stroke treatment, starting in the ambulance.

The CT ambulance has been seen to increase the efficiency between staff, both in the prehospital care and in the hospitals. This might be a result of all staff using the same system, making interpretation easier. It has also been seen to decrease the DNT.

However not discussed in the study is the large cost of implementing the MSU as a solution in the prehospital care. It is mentioned that the MSU should be dispatched together with an ambulance to ensure correct care if the patient is not suffering a stroke. [52]

A patient's condition is often unknown, in this case the MSU might be unnecessary, costly and resource demanding. This is a problem that needs to be solved before implementing the solution into reality. The system is best implemented in cities, while implementing the solution in rural areas is not feasible due to few patients. [30]

### Comprehensive Stroke Centres

Comprehensive Stroke Centres, CSC, have been researched and developed during the past decade. The idea is to mimic and use the model of trauma centres. Comprehensive stroke centres are fully focused on stroke care and possess the best and most specialised knowledge of stroke treatment. CSC's are larger stroke units placed regionally.

When analysing the possibilities for CSC and trauma centres the benefit is shorter time to actual treatment. Not all hospitals can have stroke centres, due to the volume of patients. If the volume would have been bigger more stroke centres might have been possible, but to maintain and achieve the expertise and make the centre feasible the centres need to be located regionally.

It has been shown that trauma centres with a high volume of treatments obtain better outcome after treatment as well as a lower risk of treatment. The result is due to the increased expertise and the conclusion is that the same benefits would be seen in a stroke centre. [54]

### Measuring Vital Signs Afar

Systems for detecting vital signs afar by video analysis are also an upcoming area of research and clinical integration. The company Oxehealth has created a system for monitoring patients in beds at hospitals by using an IR-camera. The system can track heart rate and breathing rate by analysing the colour change of the skin and the movement of the chest, even if the patient is covered by a blanket. The system can also be used in psychiatric wards, home monitoring and police detention centres. The system is entirely non-invasive and includes IoT solutions. The system is not specific to stroke care. [55], [56]

### Current Stroke Scales

To improve stroke assessment, there is a need for an integrated regionalised network of care. Currently, different cities, states and regions are developing individual systems for stroke assessment. The systems involve different ranges of healthcare components based on rules and regulations. The choice of where to transfer a patient is burdening and many external factors affect the transportation routes, see table 4.1. Creating an established regional plan for transportation of stroke patients could give the paramedics better support in the decision making. [15]

The parameter most frequently discussed in stroke care is time, a parameter not directly incorporated into any scale. However, all prehospital stroke scales include a rapid decision making. For example some scales determine if a stroke alarm should be issued and which route the patient should be transferred. To achieve a faster care

there are three parameters that have been proven to affect the parameter of time the most. The three factors are: the severity of the stroke, the age of the patient and if the patient is transported by ambulance. The largest delay is caused by people hesitating to contact the medical services. The delay was in year 2011 analysed as possible to overcome by raising the awareness of the population, thereby creating the Act FAST campaign. [57]

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Capacity
Distance
Traffic
Weather
Geography
Options (Vehicle/Helicopter)
Time from symptom onset
Stroke severity

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**Table 4.1:** Factors affecting transportation choices.

## Video Analysis

Different options of cameras possible to integrate in the suggested solution were mentioned in the interview with Klas Bengtsson from Metrics Solutions. The interviewee stated that the choice of camera is of less importance, the result of the suggested system will mostly depend on the software. The result of the interview was strengthened by the found literature which concluded that video analysis as a technique is present but not widely used in the healthcare area. The suggested system should include cameras which create raw data, not compressing any information. A smart camera carries out calculations within the camera whereas a standard camera can be combined with external software in order to perform calculations. [58]

There are some important overall steps in the facial feature algorithm which the demo of the suggested system focuses on:

**Face Detection and Segmentation:** Separate the face from the background.

**Face Features Detection:** Find the facial landmarks in the image.

**Face Normalisation:** Normalise the face by resizing, scaling, rotating and correcting colours.

**Feature Extraction and Descriptor Computation:** Use the quantised measurements derived to calculate the relative distances between facial landmarks.

**Validation and Classification:** Verify the result.

Important factors for a good function of the suggested system are computation speed and precision. Important factors regarding the image are for example the image resolution, sharpness of the image, the angle of the image and lighting.

The steps of segmentation, feature detection, feature extraction, classification and verification will be further discussed in sections below.

## Segmentation

Each frame in the video collected should be segmented. Segmentation of an image is simplified by static camera placement, fixating both angles and position. The easiest segmentation is background subtraction. It can be performed if the background is known before the object is present in it. Background subtraction is sensitive to variations in illumination.

A moving, dynamic camera complicates the segmentation. This is because the background and the object will both be moving. If using a dynamic camera, an idea is to use temporal differences or optical flow to segment the image.

Other known difficulties in tracking a person's movement are if the angle of view is unknown at start or if the angle can change. All humans vary in looks, something that makes determining unusual behaviour or appearances harder. It is also difficult to choose good features to model what is searched for. Disturbances in the images such as shadows, more than one human, the stretcher and other devices may be introduced while analysing. [59]

## Feature Detection

Facial landmark detection is a computer vision topic of detecting distinctive features in human faces automatically. Facial landmark detection is also called facial feature detection. It is a topic that has developed during recent years. There are different types of landmarks used for detection in images. The three types are called anatomical landmarks, mathematical landmarks and pseudo-landmarks.

Anatomical landmarks are visual landmarks in the image. These landmarks are often assigned as ground truth by an expert. Examples of anatomical landmarks in a face can be seen in figure 4.1.

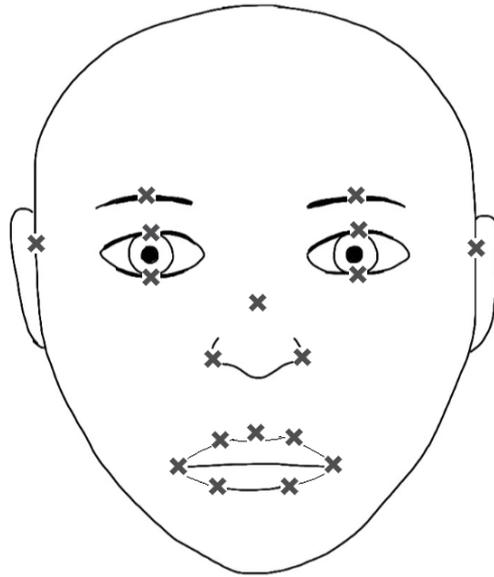
Mathematical landmarks also called geometrical landmarks are described by features within the image. It could be a large gradient change, maximum curvature or another extreme point. Mathematical landmarks are computed from the image.

Pseudo-landmarks are landmarks placed in between the anatomical and mathematical landmarks. Pseudo-landmarks are created with an even space between them in order to create more landmarks in an image.

There are 18 standardised anatomical landmarks determined by the International Registry for Neuromuscular Reconstruction in the Face. The 18 landmarks can be seen in figure 4.1.

There is also a standard for 3D face and body models called MPEG-4, which describes many more standardised anatomical landmarks. [60]

Landmarks can be validated by comparing them to known landmarks. This is performed to determine if the landmarks correspond and are describing the same part in both images. For example in one image more landmarks may be found than in another image. To determine that all found landmarks are true landmarks and not caused by an artefact, true landmarks are compared to the found landmarks in the image, non-corresponding landmarks can be ignored. [61]



**Figure 4.1:** The 18 standardised facial landmarks.

## Feature Extraction

Feature extraction, also called landmark extraction can be performed in multiple ways. A feature is an interesting part of the image, such as an edge, an object or a point. It is important to find features that model the differences to be classified.

The use of the Space-Time Volume, STV, creates a representation in 3D describing the image in  $x$ ,  $y$  and time span and detects space and time relations. However this method is sensitive to non-periodic activities included in the suggested system. The Discrete Fourier Transform, DFT, finds variation in intensity through the frequency transform. This is used to find geometric structures of an object. Both STV and DFT are global descriptors, describing the entire image.

There are also local descriptors describing a region of interest. For example this may be the Scale Invariant Feature Transform, SIFT, which calculates key points invariant of scale, rotation and translation. One could also use Histogram Oriented Gradients, HOG. For fist-tracking implementation a new method has been used. The method is called LKT, Lucas-Kanade-Tomasi. Local descriptors may be used if a patch of the image is to be analysed, which creates invariance to rotation, scale, clutters, appearance and occlusion. However, it can not model the whole body of actions. One could also analyse trajectories and velocity. [59]

## Artificial Intelligence and Classification

Artificial intelligence, AI, machine learning, ML and deep learning require large amounts of data, which is hard to access in Swedish healthcare. Many problems arise by demanding patient specific data. Decisions on what data that should be gathered and how missing data is handled is important to understand. There is a need of a standardised way of gathering the data and the system has to be able to describe what the data is modelling.

A statistical model finds relationships between variables. It is possible to understand the relationship between two included variables. Statistical models are mathematical equations with assumptions created from observed data. To use statistical models require the understanding of relations between variables.

An AI or ML system learns from the data but the model is not rule based. The result relies on the predictive accuracy of existing models. No effects of single variables are shown in the output. There are no predetermined relationships between the predictors and the outcome.

A study comparing the outcome of statistical models and AI/ML models have shown that simple statistical models may give a result as good as using artificial intelligence for classification.

The conclusion in the study is that the quality of the data used improves the outcome more than including complex classification models. It is better to place resources in pre-processing the data than to develop more complex classifiers. [62]

The user interface and the visualisation of the data are as critical for good function as the calculations performed. It is harder to interpret the output of an AI system than the one from a regular statistical model. A result from an AI system could be created by millions of layers, making the result unexplainable to a human.

In a study on interpretation of Sepsis in the prehospital context, better assessment of the symptoms was reported when including free text from the EPR's in the result. This is an important factor showing that the assessment scales used do not cover the entire illness. It is important to understand that illnesses are dynamic flows making the data dynamic. The system should therefore be able to track dynamic changes. Sepsis can be compared to stroke because it is very hard to determine in a prehospital setting, and there are many mimics to Sepsis symptoms. [63]

The choice of classification algorithm will decide the function and outcome, a choice which has no standard answer. A classification algorithm usually needs training data to learn how to make the decision. Some examples of classification methods previously used in analytics of healthcare and chronic diseases are Support Vector Machine, SVM, Artificial Neural Networks, ANN, Logistic Regression, Random Forest, Naïve Bayes, Kalman filter, Decision Trees or K- Nearest Neighbours among many more. To reduce the effect of imbalanced or missing data fuzzy logic could be used. Fuzzy logic includes many not as independently strong parameters which together create and strengthen the result from the classification, it is good at handling noise in the data. More than one parameter will be needed in order to create a support in the assessment. No single parameter can determine a stroke but multiple parameters joined can create a stroke assessment. [59], [64]

## Validation

Testing the system on simulations of stroke with healthy subjects could be a first step of verification. As a start, a small amount of data or test people could be used to try out functions, formats and data representation before applying it to bigger scales. By using such a technique, unnecessary work can be minimized. To test in a simulated environment is also a way of decreasing the risk for patients. The system should initially implement statistical models for classification. This solution does not require a vast amount of data before the system can be completed. By pointing out important landmarks and movement patterns the system could be used with very little data, more as a system enhancing the reality than for classification. The use of statistical models will reduce juridical limitations which could include a quicker

market entry time.

The output needs to be verified to ensure that the system provides more benefit than harm. Many tests and extensive data are needed to validate the system. A database with gathered assessments is needed to allow the verification of the output as well as the different algorithms to choose from when developing the system. The algorithms for classification may change with time due to new knowledge of the condition or classification. It may also change if more data is included.

## Quantitative Measurements

Following sections describe the derived quantitative measurements for implementation and the current use of the factors mentioned.

### Measurements of Eye Movements

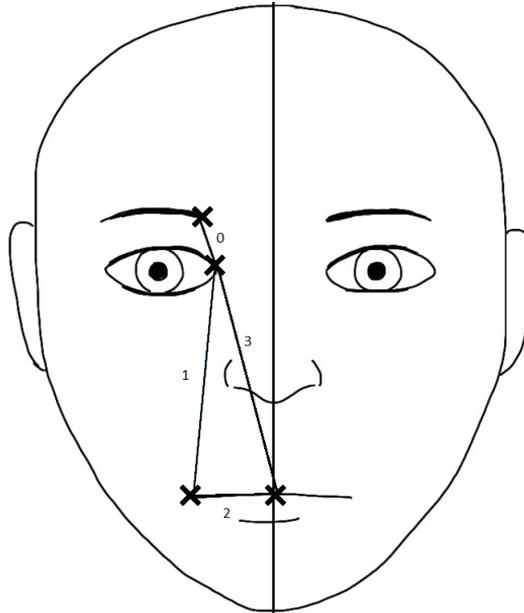
Many models for gaze- and eye-tracking have been developed during the last decades. Some implemented solutions have been clinical but it is more regularly used in other areas such as analysing driver's tiredness and shopper's behaviours. In the healthcare sector the area of eye- and gaze-tracking has focused on diagnostics of psychological disorders as well as a teaching tool for professionals. The teaching tool includes gaze-pattern analysis of professionals interpreting medical images. By analysing the gaze-pattern, knowledge of important sections in the image is created. [65], [66]

A study regarding neglect and extinction covered the analysis of one woman's vision by gaze-tracking. The study concerned fixed visual targets for testing the wide-angle and central view. The patient had suffered an ischemic stroke that mainly affected her left side. The study concluded that gaze-tracking creates information of the visual fields, fixation times and gaze-patterns. The study concluded that the method could be used even if the patient showed cognitive reductions. The study also mentions recent progress in low cost eye-tracking devices as well as free software available, making the introduction to clinical use more likely. [66]

### Measurements of Facial Asymmetry and Head Movements

Studies determining quantitative measurements of facial asymmetry have been completed primarily for research and clinical use within orthodontics. Measurements of facial asymmetry have been used to model how to surgically improve the outcome after a cleft palate and to determine the outcome after surgery on facial paralysis. Identification of psychological disorders has been investigated to analyse micro-expressions and anticipate possible outbursts. The systems in the studies mentioned have used 3D imaging through IR-cameras in order to view the entire person. The software used in the studies was initially used as a commercial product in cars to track the drivers gaze and detect if the driver was tired. The function was further developed to be used in clinical testing. The systems used 2-5 cameras that could be positioned freely. The precision of the system included marking of certain anatomical landmarks with black dots. [67]

A study on quantifying the upper and lower facial muscle functions for patients suffering from hemispheric stroke has been conducted in Switzerland including 27 hemispheric stroke patients and 22 healthy participants creating a control group. [68] Four facial distances were measured in each participant, see figure 4.2 and table 4.2.



**Figure 4.2:** Facial distances for detecting asymmetry.

0	Inner Canthus to Eyebrow
1	Inner Canthus to Oral Commissure
2	Oral Commissure to Mouth Mid
3	Mouth Mid to Inner Canthus

**Table 4.2:** Description of facial distances.

The study determined that all patients within the patient group, PG, had a longer distance from the inner canthus to oral commissure on the impaired side in all poses. The study also confirmed that the lower facial muscles are more affected by a hemispheric stroke than the upper facial muscles, the measured absolute distances varied more in the PG group. The distances compared in the PG group were the affected and non-affected sides. The variability was measured as standard deviation. To avoid bias relative distances were calculated as well as absolute distances.

The Swiss study used an infrared 3D video system made up by two cameras and mirrors. The software measured distances between landmarks by freezing the video. The system did not demand special lighting, fixed angles or static distances. A critical aspect of the Swiss study was that long time had passed after the stroke until the study was completed. The time passed may have resulted in improvements created by rehabilitation, the differences could have been bigger if tested at an earlier stage. [68]

An Austrian study involving 24 participants all with middle European descent has been completed to determine the average distances between facial points of healthy people. The 24 participants were divided into three groups of eight, each group consisting of four men and four women. The three divisions were 20-30 years old, 40-50 years and 60-70 years. Facial features differ with ethnicity, gender and age,

therefore all participants were chosen to be within the same demography to make comparison easier.

The Austrian study covered 18 standardised detected anatomical landmarks marked with black dots on the face of the participants. The landmarks can be seen in figure 4.1. Out of the 18 standardised landmarks, three were static anatomical landmarks and 15 were dynamic anatomical landmarks. The three static landmarks were used to calibrate the system. These 18 landmarks are standardised by the International Registry for Neuromuscular Reconstruction in the Face. [60]

The participants were asked to repeat predetermined facial movements three times, the best recorded movement out of these three was analysed. The recordings were completed in a controlled environment using the same chair, lighting and position at the same hours throughout all tests to reduce the variation in noise.

The quantitative result showed that males have longer distances and also larger movements than women. Males have larger facial dimensions and women have smaller faces than men. All participants showed asymmetry. The asymmetry was more visible during rest than movement. Asymmetry in movements was more evident in the middle and lower parts of the face. Asymmetry increases with age, but age had no significant impact on asymmetry during movement. [60]

## Measurements of Extremity Drift

Studies have covered the distribution of muscle impairment after stroke. Historically the conclusion has been that the proximal muscle strength is less affected by a stroke than the distal parts. It was also thought that extensions of joints are less impaired than flexion strength and that the contralateral side to the stroke is the one affected. Research from the 21st century has resulted in partially other conclusions.

In a study covering strength deductions after a stroke the muscle strength was tested by using a handheld dynamometer performing eight different movements. The study concluded that strength is impaired contralateral to the lesion, but there was also smaller bilateral strength impairment. The impaired strength was more affected in distal than proximal muscles. The extension strength was less impaired than the flexion strength primarily in the upper limbs. The result determined that lower limbs strength was more impaired than the upper limbs only on the stronger side. [69]

## Other Quantitative Measurements

Bite force, lip force and chewing efficiency have historically been seen as indicators of stroke. The reason is that hemi-facial paresis leads to orofacial dysfunctions.

A study concluding chewing efficiency, bite- and lip-force of stroke patients measured the strength in the midline of the mouth by a digital force plate. The strength would have been better tested if tested on both sides, since the information on side weakness is interesting when researching stroke. The study concluded that masticatory efficiency and maximum lip force are severely affected by stroke, but maximum bite force was not. These are known possible signs of stroke that are not currently assessed. [70]

Other signs found connected to stroke but not yet assessed are for example breathing frequency and muscle strength through electromyogram, EMG. Hypoxia, defined as a loss of saturation for more than five minutes is common in stroke patients. This factor is usually underdiagnosed and often not treated. Hypoxia can be caused by a brain stem stroke and hyperventilation may be induced by a

critical damage caused by a stroke. A brain stem stroke is as earlier discussed hard to assess. Detecting breathing frequency could be completed through video analysis, throughout the entire care process, not only in a prehospital assessment. [55], [71]

Muscle strength determined by EMG measurements has been investigated to extend stroke assessment, but it is hard to implement as many electrodes are needed which increases the time of an assessment. Instead the method could be used to assess the progress of rehabilitation. Muscle strength could also be tested in a similar test as the bite force, by using force plates or a handheld dynamometer, however the solution requires more sensors than solely video analysis to work. [72]

None of the quantitative measurements mentioned in this section are currently used for assessing stroke. Some of the mentioned measurements include video analysis and some do not. These measurements are mentioned in the report primarily to broaden the reader's understanding of factors which are known signs of stroke but not currently assessed. There are of course many more ways to assess the measurements described above.

### 4.1.2 Interviews

Below are summaries of the interviews held. All interviewees have agreed on what they said and to be referred to in this report.

#### Interview with Expert in Telestroke

The interview took place in Gothenburg with Bengt Arne Sjöqvist, professor of practice at Chalmers University.

According to the interviewee, deciding which hospital to transfer a stroke patient to introduces the same problems as the openings of trauma centres did. The main question is if the benefit of the increased knowledge at a stroke centre will compensate for the prolonged time of transfer to the stroke centre compared to a regular hospital.

A factor determining if the patient should be transferred to the closest hospital or to the closest university hospital is often if a thrombectomy should be performed. Time is saved if it was the correct call to transfer the patient to a university hospital, but if shown that thrombolysis should be issued instead, it was not the correct choice to transfer the patient the longer distance.

Where to transfer a patient is an important and burdening choice, and it is a reason why telestroke is increasing in popularity. The Swedish Association of Health Professionals trade union have been brought in to this question in order to strengthen the paramedics' rights. According to the trade union, the burden connected to the decision of which hospital to transfer the patient is too big for the individual paramedic. The decision should be made by multiple people assessing and together reaching the decision in order to not affect the individual if something goes wrong.

Many if not all county councils have developed their own platforms for handling video content. The platforms include framework demands on the data and devices connecting to it. These platforms have been made somewhat regional to better comply with interoperability.

It is important to understand that especially within the healthcare sector transformation takes time. Different areas should be interconnected and cooperation is needed. A project must be introduced through a clinical perspective with a long time frame. To include new technique in healthcare and to digitalise functions will meet resistance. [73]

## Interviews with Paramedics

The individual interviews took place in work surroundings at Västerås prehospital care unit. The interviewees were Fredrik Wretman and Magnus Carlsson, paramedics at Västerås prehospital care.

The paramedics at Västerås use an outline but no standardised way of initial stroke assessment, making an assessment harder according to the interviewees. The interviewees want to underline that the FAST pathway is followed but the individual assessment rules are not standardised. One paramedic might ask the patient to squeeze the paramedic's hand, another to first cross arms before squeezing and a third to lift both arms to a certain degree. In the end this tests the strength in the arms, the difference is created by difference teachers.

When paramedics arrive to a scene they usually have information describing the patient's symptoms given by the dispatchers. The paramedics always check vital signs of a patient, no matter what diagnosis they suspect. ABCDE - Airway, Breathing, Circulation, Disability and Exposure is an overall clinical triage pathway used in Västerås prehospital care that assesses vital signs. Another method used in Sweden is called RETTS, Rapid Emergency Triage and Treatment System. This method can be compared to the ABCDE method. Included in D - Disability is the FAST assessment and eye movements.

A stroke assessment is often spontaneous and includes a mix of observing the patient and completing the steps of the clinical pathway. The assessment is almost always completed at home, if the patient is picked up from home. The paramedics try to not do the initial assessment in the vehicle since there is a very limited amount of space, which might prolong the assessment. There might be multiple assessments to see how the condition is evolving, on the way to the hospital if the transport distance is long.

Remote doctors more frequently decide to issue a stroke alarm than not. In many other areas the paramedics have over the years received the power to make care decisions, but in stroke care the decision has to be made by a doctor. This is due to the standardised way of issuing a stroke alarm. The paramedics do not have the right to issue a stroke alarm.

A clear sign of a stroke is if there are differences between the patient's sides, a decrease of muscle strength in both sides is less connected to stroke because it may depend on other conditions. The paramedic can not compare the strength to before the suspected stroke happened.

The most important effect of the suggested system is as support in grey-areas. The interviewees agree that it must be a doctor that assesses if the route of a stroke alarm should be followed. The doctor can analyse the symptoms better, include prior conditions and get an overview of the anamneses. The interviewees state that the system will be most beneficial for the doctors and give them an extra dimension to be used for assessment.

A flow chart of care for a suspected stroke patient in Västerås can be seen in figure 4.3. If the patient is thought to suffer another condition than stroke the patient is transported to the ER, if the initial assessment is positive for stroke a stroke alarm is issued and if no harmful symptoms are present the patient stays at home. [74], [75]

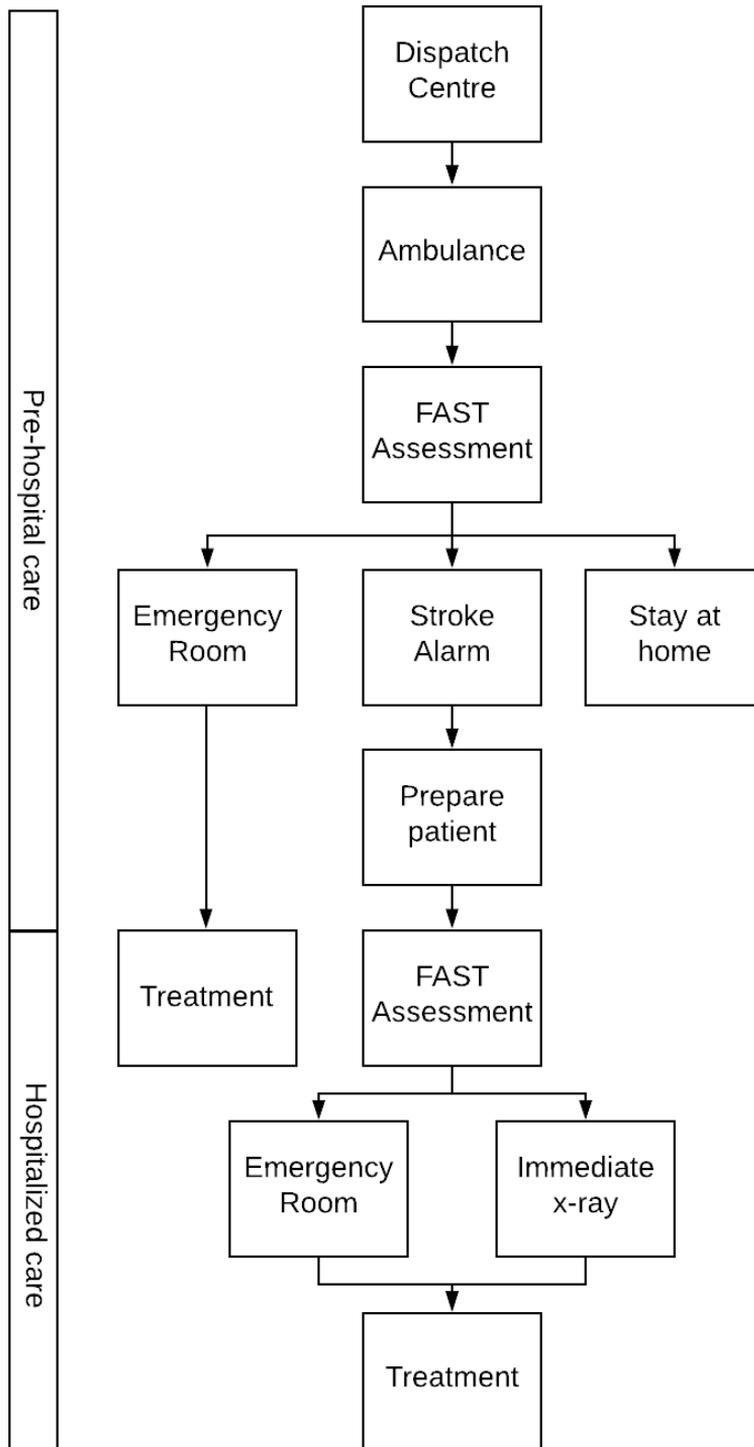


Figure 4.3: Flow chart of stroke assessment in the prehospital care.

## Interview with On-Call Doctor

Elisabeth Rooth, Head of Medicine, Facilitator of the stroke unit at Danderyd's Hospital has been interviewed. At Danderyds hospital, in the county of Stockholm, the prehospital assessment of stroke is completed using FAST, under evaluation is also an assessment tool called A2B2, which is based on a shortened NIHSS.

Depending on the outcome of the initial FAST assessment, different routes are chosen for the patient. If a stroke alarm is issued the patient should be transferred to an immediate CT. The stroke alarm allows the doctors and nurses at the hospital to prepare for the patient. The doctor meeting the patient upon arrival to the hospital concludes a second FAST assessment in the lift on the way up to the CT to further minimize the time.

In the ambulance all vital signs are measured. The interviewee says that if some measures are off it implies that the condition is something other than a stroke. Vital signs are therefore more a way to exclude other illnesses than prove stroke. All stroke symptoms, listed in table 2.2, appear momentarily at the start of a stroke and are possible to assess already in the ambulance or at home.

The interviewee says that it would be possible to quantise measurements to conclude facial hemiparesis or weakness in the body. However she stresses that it is normal to have a degree of asymmetrical appearance. The variance could be large even if the patient does not suffer from hemiparesis. The patient might also have other conditions mimicking stroke. The interviewee can not see any improvement with including automatic video analysis in prehospital stroke assessment. She thinks that the best solution would be if the on-call doctor could interact directly with the patient, i.e. telestroke. This would mean that the doctor could create his/her own opinion and prepare thereafter.

The interviewee says that the doctors are probably better than a paramedic at determining lower scores of stroke. The interviewee also implies that there is a difference between different doctors in the outcome of the diagnosis of stroke.

The interviewee mentions some important factors to take into account when developing the suggested system. Communication with a doctor will still be needed, the system must not replace the doctor. The system must not interfere with the paramedic's work. Therefore the solution must be integrated to everyday work in an easy way. To detect the changes searched for, a standard camera would be enough. The interviewee gives a suggestion to use a wearable camera attached to the paramedic's head during a prehospital exam. Legal aspects of filming a patient need to be considered. One would also need to get patient consent, something that might take time but also be impossible for some patients. As for now there is no simple solution for receiving consent from an unconscious patient or a patient suffering from cognitive reductions. The outcome is that intensive care patients most often are non-applicable for cooperating in studies. [76]

## Interview with Creator of a Prehospital Stroke Scale

Magnus Esbjörnsson is a neurologist at the hospital of Hässleholm and the co-creator of the stroke scale preHAST, the interview was carried out in Hässleholm.

The interviewee mentions that current stroke scales include interrater variability. Most stroke scales derive from or can be approximated to the NIHSS scale which describes why all scales suffer from the same disadvantages. A trial in Hässleholm including video-cameras in ambulances was an ongoing project from 2010-2015 founded by Vinnova. Magnus Esbjörnsson was the doctor leading the trial at the

hospital in Hässleholm. An ambulance was equipped with two Axis cameras, one microphone, one speaker, a computer program, an application where the remote doctor could log-in and a router containing four sim-cards with different operators to ensure connection at all times. The system was tested in rural areas and the connection maintained sufficient in almost all areas.

During the test time period approximately 100 patients suspected to suffer a stroke were assessed using the video-ambulance. The aim of the study was to test the technical functions of the system. Therefore no data was stored and no ethical approval was needed. The consultation through video-link was always combined with an initial assessment by the same doctor at the hospital to validate the symptoms.

The result of the study showed that the resolution of the cameras and the lighting in the ambulance were satisfying and no disturbance caused by the cameras' shaking was detected. A doctor can detect more critical aspects if viewing the patient instead of listening to the paramedic retelling the assessment. Higher values of NIHSS or similar scales imply a big stroke, these strokes are often correctly determined by the paramedics and/or via phone. Lower scores are harder to assess correctly. Some strokes may be major but in an area of the brain that does not show any high scores on the scale used. A stroke in the cerebellum or in the brainstem will often result in low scores in prehospital stroke scales. The reason is that some functions are not easy to rapidly assess, not included in the scales or too time-consuming to evaluate in the prehospital care.

The main disadvantage of the system was the quality of the sound, a problem caused by difficult set settings. The doctor could usually hear the users in the ambulance but the users in the ambulance had difficulties hearing the doctor. The streaming of video from the ambulance to the remote doctor was affected by a varying time delay and disruptions in the video-stream. To identify if the reaction of a patient is slow or if it is a time delay caused by the remote video is critical for the overall assessment. Equally a disruption in the stream may look like the patient exhibits Ataxia although it might be caused by the transition of data.

Included in the system were covers placed over the cameras. The black covers were used to protect the paramedics and the patients. To use surveillance in an ambulance might not always be convenient. If the patient for example is psychotic it might affect them very negatively if thought to be monitored. The paramedics should not feel as if they are being monitored or evaluated at all times, therefore the possibility to cover the cameras was found to be of big importance.

Since stroke patients often have stable vital signs the time transferring a patient to a hospital has been identified as a possible time to complete more accurate and precise assessments. This motivates placing the cameras inside the ambulance. Some functions affected by a stroke, for example Aphasia and Neglect may cause quenching phenomena which means that the patient is unaware of the functions in one side of his/her body. This is shown in a DNT being twice as long for patients experiencing quenching. The patient is unaware of the symptoms because they can not notice them. The function losses can be detected by others, therefore it is more common that a relative identifies a stroke. The risk of not receiving care in time is larger if the patient lives alone.

The factors best determined by a semi-automatic system are, according to the interviewee, based on facial movements and extremity motor skills. Eye movements can be tracked during the entire transport. If the eyes drift to one side or lock in position, it may be a sign of stroke. The drift or locking of the eyes might be possible for a patient to willingly overcome, if asked to do a certain move and therefore it

might be missed by the paramedics. A sign that is subtle but usually connected to a stroke is a change in the wrinkle from the nose to the corner of the mouth. Many not so experienced professionals have difficulties differentiating between Ataxia, loss of coordination, and paralysis. Cerebral Ataxia is mostly shown as a pecking motion whereas paralysis may result in for example not reaching the nose when trying to.

A positive result of the video and phone communications with a remote doctor is that EPR's can be viewed. The reason the paramedics can not access this information is according to the interviewee legal. The Swedish ambulance care is in many county councils driven partly or entirely by an independent company. The transfer and access of the EPR's can not yet be determined safe and it is therefore not implemented.

Another area of use for the suggested system may be in the hospitalised care. Patients suffering a TIA are more at risk to suffer another TIA or stroke within the first 24 hours. Therefore the patients are closely monitored by staff and woken up every other hour to be tested to see if symptoms are deteriorating. By monitoring these patients, maybe by using an IR-camera, the patients could get much more sleep and not be disturbed in the recovery. [77]

### 4.1.3 Observations

The observations took place in the emergency service in Västerås, Sweden, during one day. The observations resulted in a better understanding on how to model the system and how to integrate the different components in the already busy environment of an ambulance. It was also beneficial to ask first-hand what difficulties the paramedics experienced with the current ways of assessing a stroke, and what they thought could ease the job.

When observing the author had not decided the layout of the system. This meant that the choice of placing the cameras inside the ambulance or somewhere else had not yet been made, all areas of interest were equally investigated.

An ambulance is very crowded. All devices mobile or not must have a certain dedicated holder or place, the user must know where to place the device when finished using it. In an ambulance two paramedics are working. The two paramedics both handle the patient, but when transporting the patient, one paramedic drives and the other paramedic cares for the patient. The patient is placed on a stretcher, it is also common for a relative to travel in the ambulance.

To measure vital signs the patient is connected to ECG and other measuring devices, creating even less space. To prevent devices from breaking and getting lost a static placement of all devices is desirable. There are requests that the initial stroke assessment should not be completed inside the ambulance due to lack of space.

## 4.2 Data Analysis

The data collected had to be structured and analysed. The section below describes the results from the data analysis. This section is where the suggested system is described and takes form.

### 4.2.1 Mapping of Users

Stakeholders of the suggested system are the society, the company creating the product, the suppliers, the government and competing companies but it also includes the users determined below.

The primary users of the suggested system are paramedics. Secondary users are stroke experts i.e. on-call doctors, examining the information. Tertiary users could involve the social board, management at hospitals, dispatchers, after care givers, relatives and patients. The secondary users currently have a big influence in the final assessment of stroke and should be highly prioritised in the development of the system.

#### 4.2.2 Brainstorming

The result of the brainstorming method mind mapping is shown in figure 4.4. The mind map displays different choices of solutions. The mind map resulted in six branches to focus on when creating a technical specification of the system.



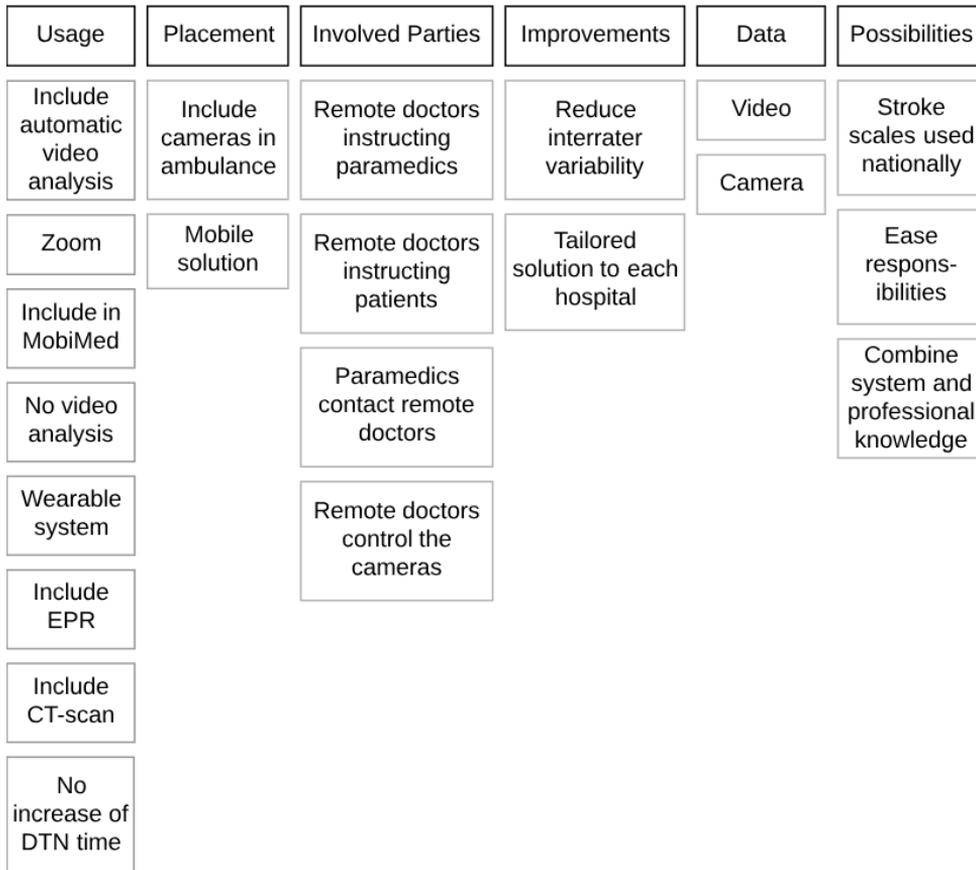
**Figure 4.4:** The mind map created by brainstorming.

Another brainstorming session was completed by writing down demands on the system concluded from interviews on separate pieces of paper. The result from this brainstorming session created an affinity diagram, see figure 4.5.

The two brainstorming methods were of big importance for the results. The methods gathered and structured the data. By using the brainstorming methods, ideas could be generated and iterated, creating a solution which is thoroughly thought through and includes the best found options for creating the suggested system.

### 4.2.3 Affinity diagram

The affinity diagram is shown in figure 4.5. The result of this method created six overall themes, which can be seen in the top row of the affinity diagram.



**Figure 4.5:** The created affinity diagram.

The found themes described the stakeholders' demands on the system. Some are contradictory and had to be discussed and iterated thoroughly in order to be determined into a function. The functions of the system have all been derived by using the themes determined by the affinity diagram.

### 4.2.4 Functions

The system should be able to track various parts of the body of a patient, both individually and at the same time. This will be done by using three cameras recording videos.

The system shall allow the primary user, which is the paramedic, to interact with the system, the user can override the system both by deciding what test to perform and by making the final decision of assessment.

The system ensures secure transfer and storage of data, both internally and externally. The system can store and send data which is compatible to be stored and directly transferred to the patient's EPR.

The system is included as a part in a bigger system, which includes the EPR, for example in MobiMed.

The final system can classify and give substantial recommendations to the paramedics. The system is proven useful and accurate before used in reality. All users are informed that the final decision is always made by the paramedic or a remote doctor.

The system should help the user to follow a standardised pathway for assessment. The system must be manually started, but once started, it is collecting data continuously. The system can always be controlled by the user, but if not controlled, it still identifies risk parameters and warns if indications arise.

The system combines professional and system knowledge to reduce the interrater variability of current stroke scales. The suggested system uses augmented reality solutions to support the user before substantial data is gathered for validation. This is completed to ensure that the system's assessment is correct.

### 4.2.5 Use Case

The derived use case regards the same case as the demo. The demo and the use case assess the asymmetry when a suspected stroke patient is smiling through facial feature detection. The use case is narrow but it describes in detail how the modelled function would be used by four different actors. The use case covers the system interaction from start of assessment in the vehicle until a stroke alarm can be issued.

**Use Case:** Assess Facial Asymmetry when Smiling

**Primary Actor:** Paramedic

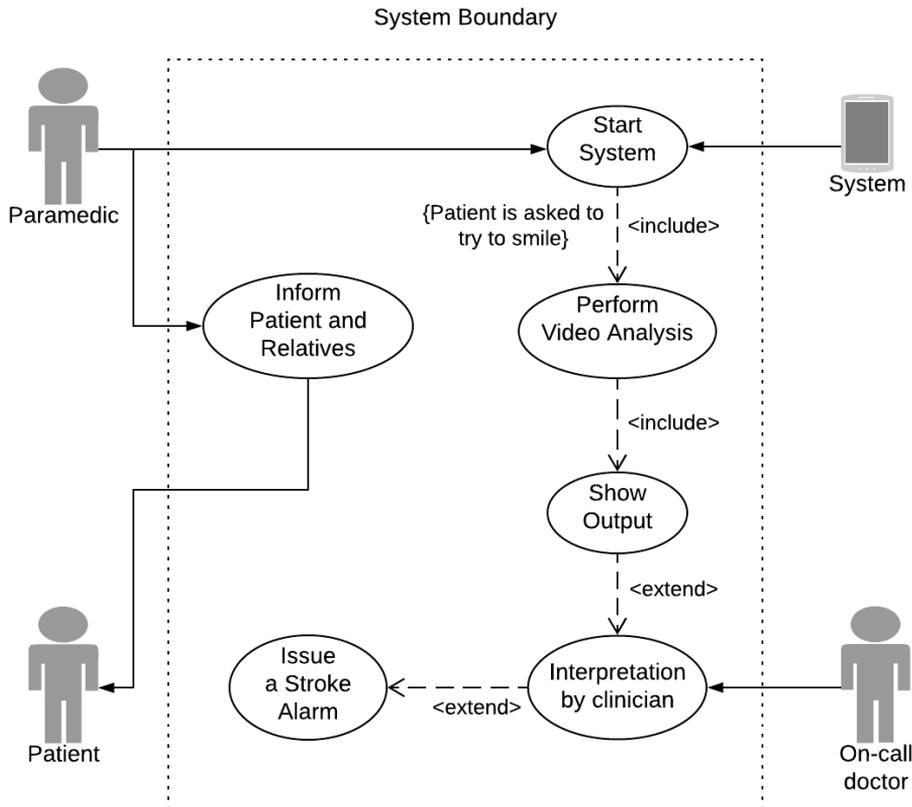
**Scope:** Assess the facial asymmetry of the patient.

**Brief:** The patient is assessed by the suggested system. The suggested system supports the paramedic and the on-call doctor in determining if the patient shows facial asymmetry when smiling. If a stroke is suspected the on-call doctor should issue a stroke alarm.

**Stakeholders:** System, patient, on-call doctor and paramedic.

The use case defined is visualised in a UML use case diagram describing the facial asymmetry tested when a patient is smiling. See figure 4.6.

The use case describes one of many functions included in the suggested system. More use cases describing other cases can be derived to model how the user will interact with the system. To describe the system is important in order to ensure that all stakeholders understand what can be expected from the suggested system.



**Figure 4.6:** The use case UML diagram for facial analysis.

As previously described a use case can be built up in different ways depending on the aim of the use case. The aim with the created use case was to increase knowledge of the system to stakeholders other than technical stakeholders.

The first interaction with the system is performed by the paramedic. The paramedic starts the system inside the ambulance after an initial triage has been carried out in the patient's home. A stroke sign should be present for the suggested system to be used. When the paramedic starts the system the system actor is triggered. To start the facial feature analysis the paramedic has to ask the patient to try to smile, and the patient has to be cognitively active.

Once the patient attempts to smile the system completes an analysis and shows the output of the analysis. If the output indicates a stroke the information should be referred to an on-call doctor that manually interprets the video analysed by the system. If the doctor also assesses the condition as a stroke a stroke alarm is issued and the use case is completed.

At the same time as the paramedic completes the stroke assessments he or she should also inform the patient and relatives if possible, to ensure that the patient understands what is happening.

The interpretation performed by an on-call doctor and issuing a stroke alarm have been chosen as *extended* functions because they may or may not be completed depending on the output of the system.

The video analysis and the visualisation of the output are not optional. The two actions will always be included if the system is started. Therefore these two actions have been set as *included*.

## 4.3 Specifications

The specifications of the suggested system are divided into areas determining technical, functional and user-experience requirements, all created to form an understanding sufficient to all stakeholders included in the system.

### 4.3.1 The Conceptual System

The suggested system is based on three video cameras statically placed inside an ambulance. The cameras are placed to film the patients face, arms and legs clearly. The system should enable the use of more parameters in the prehospital stroke assessment and by this improve the outcome by completing multiple analyses of the same assessment. The assessment should have high sensitivity and create an indication on stroke severity.

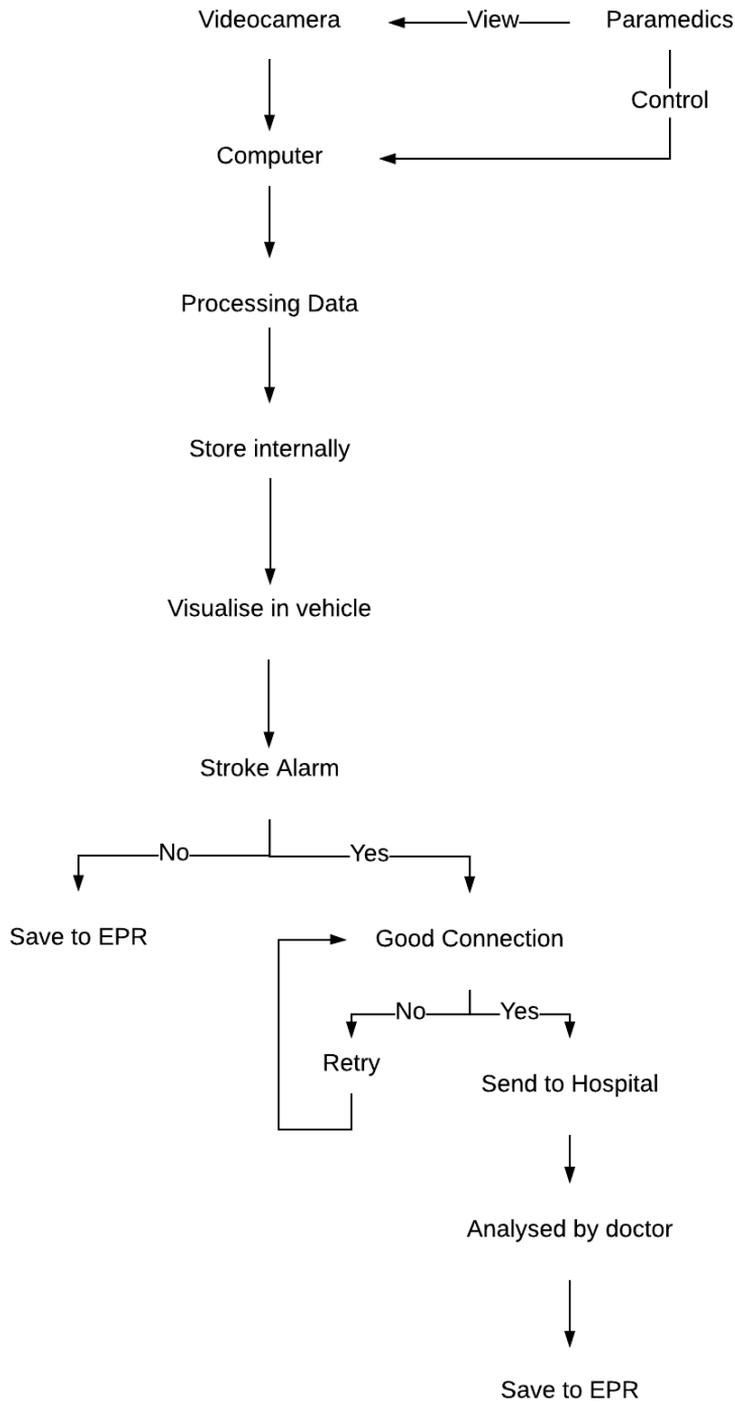
The output from the system is shown to the paramedic in real time and sent to the on-call doctor for further interpretation. Sending the analysis before arrival to the hospital can prepare the hospital professionals on the severity of the stroke. Real-time analysis in the vehicle supports the paramedics. The suggested system does not significantly affect the workflow from the current layout which is preferable both for acceptance and to maintain knowledge.

The paramedic can control which tests are completed at what time. The system records the assessment in order to be viewed by the on-call doctor and reviewed by the paramedic. The recordings may also work as an assurance for the professionals and the patient proving that the correct assessment was made. The sections below describe the suggested system in detail from a technical, functional interactive standpoint. The suggested system will not replace the rapid initial stroke assessment carried out in the patient's home but it will create an extra stroke assessment of better quality in the ambulance while transferring the patient. This second more extensive assessment will support the paramedics in their decision of transportation choice and reduce the time from symptom onset until treatment.

### 4.3.2 Product Specifications

Figure 4.7 describes the workflow of the suggested system from dispatched vehicle until treatment at hospital. The graph displays the connection between the system placed at the hospital and the system placed inside one of the vehicles. The suggested layout ensures equally as good results in rural and urban areas, since the information can be sent in chunks to the on-call doctor instead of live-streaming the video.

The system saves information and videos from the concluded assessment even if the patient is assessed as a non-stroke patient. Saving information could store evidence of why a decision was made, but if it is clear that the patient is not suffering a stroke the option to save the videos might be unnecessary. Because the paramedics can not make a diagnosis at the scene it might be better to store some extra information, since the outcome can only be predicted.



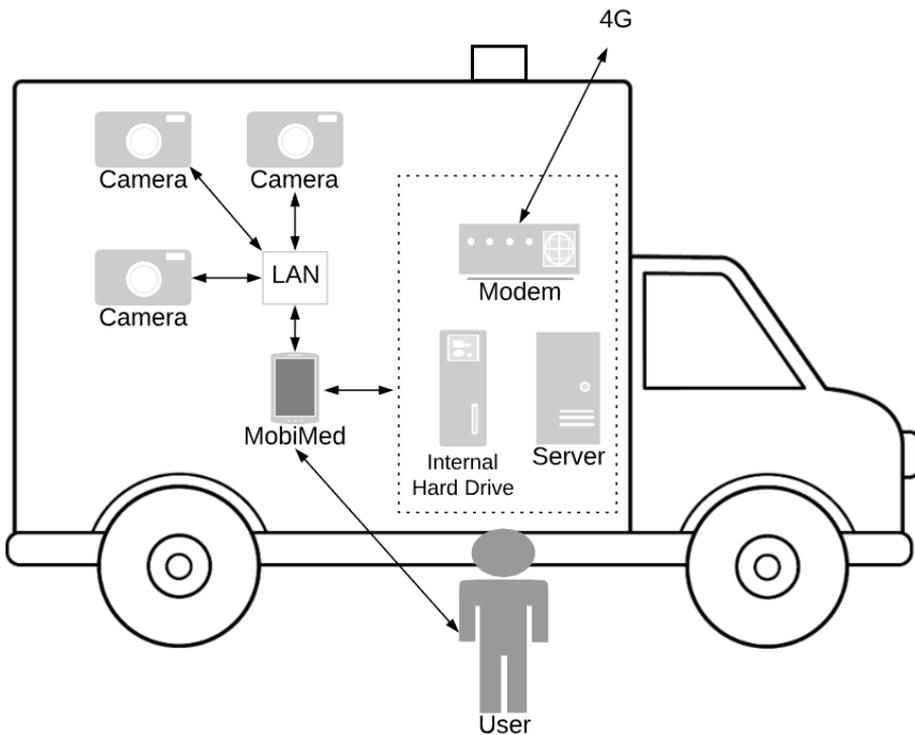
**Figure 4.7:** The workflow of the suggested system.

The two specifications in figure 4.8 and 4.9 visualise one connected system, not two individual systems.

The derived product specification of the ambulance, see figure 4.8, has a dotted square which models existing parts of the MobiMed EPR. MobiMed uses 4G and a local area network, minimizing the new technique in the suggested system to cameras and new software.

The three cameras communicate through the network and connect to the MobiMed. The user interacts with the system through the MobiMed. The data that should be sent to the hospital is sent via 4G. The server included in the MobiMed solution will require some updates compared to the existing server solution. This is because the algorithms performing the video analysis will be run on the server in the ambulance, read more in the section Video Analysis Hardware.

The mobile system in the vehicle depends on the more robust system at the hospital. The main system at the hospital receives data from the mobile system. The mobile system stores data temporarily and the main system stores data for a longer time.

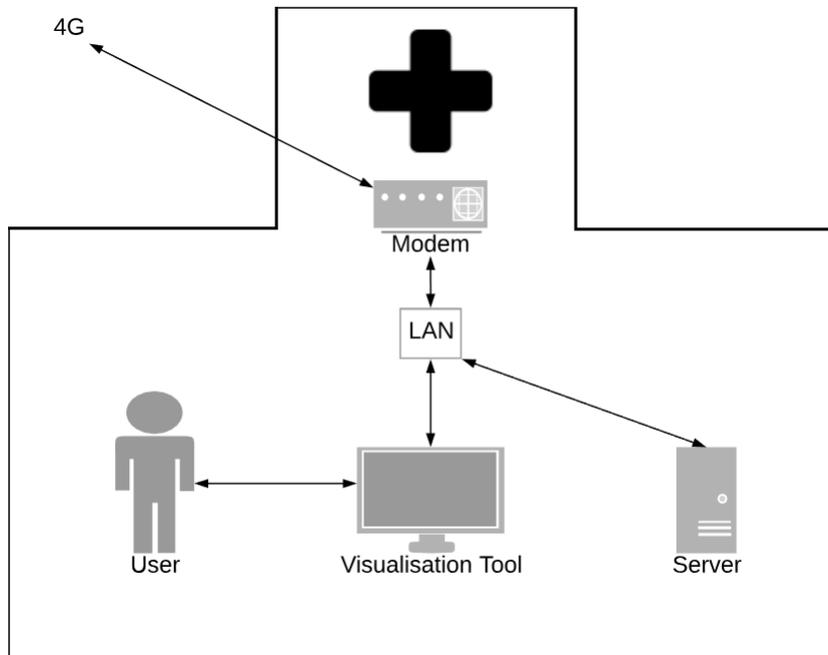


**Figure 4.8:** Derived product specification of the ambulance.

To interact with the mobile system the main system at the hospital includes clinical workstations for the on-call doctors to use, these are the visualisation tool in figure 4.9. The clinical workstations are currently used as a part of the MobiMed and Coronet systems to allow connection between the prehospital care and the hospitalised care. The layout with a mobile and a static system is also used by the MobiMed EPR. Reusing the implementation of MobiMed in hospitals would mean that the derived product specification of the hospitalised system is only in need of

new software to visualise the result from the suggested system. The use of solutions already developed by Ortivus is an advantage.

The part of the suggested system situated at the hospital communicates internally via LAN and externally using 4G. The user interacts with the visualisation tool included in the current clinical workstations. A server is needed to process and store the data.



**Figure 4.9:** Derived product specification of the hospital.

### Demand Specification

The demand specification is a list derived from the brainstorming sessions completed.

- 3 Cameras
- Image Processing Program
- Local Storage
- Network Connection
- Interoperability to EPR
- Incorporation of Stroke Scales
- Compatibility with Vital Sign Sensors
- Image Stabilization
- Graphical User Interface
- Good lighting
- Clinical Workstation
- Camera Covers
- Modem

Other aspects mentioned which are not of technical nature are the need of non-disclosure agreements, NDA's, informed consent by patients and ethical approval to

get approval of involving patients in real trials. The approvals are needed to test, develop and verify the system. It can be seen as the most critical part to obtain, without approval no further work can be done.

### Technical Specification

The suggested system should include analysis software and a graphical user interface, GUI, which displays the steps of assessment and the video from the cameras. The GUI could for example be incorporated in the MobiMed EPR system, as a part of the triage. The system is only thought to be used when some sign of stroke has been found identified.

The system has to be able to transfer data. The vehicle is already equipped with a router, but larger bandwidth may be required to support transfer of video. The data could be sent in chunks of information when for example the assessment of facial movements is completed. Thereby there is no need for live streaming of video as there is in telestroke. The video can be sent when the connection is good enough, which will reduce the lagging and the time delay otherwise affecting the system.

The users must be able to see which factors affect the output of the system for a certain patient. Local storage is needed, it will decrease the demands on the analysis of the system and make it work free of internet connection, it will therefore work just as well in rural areas. A system which is not impaired in rural areas is of big importance because the longer transfer time to the hospital the more time the paramedics have to fulfil a second assessment. The system may be more extensively used with longer transfer times, therefore has to work in all areas, at all times.

### Placement of Cameras

The placement of the cameras in the suggested system has been a reoccurring discussion throughout the project. Interviewing different stakeholders introduced different desires for the number and the placement of cameras. The decisions have been based on opinions and parameters creating the best output of the system.

Two critical reasons to the final placement of the cameras were previous conducted studies and demands to achieve a satisfying degree of quality. Keeping a constant lighting and angle of the cameras were factors that contributed to a chosen placement inside the vehicle. Fixed cameras inside the vehicle also created the ability of including more than one camera in the solution. See figure 4.10 for the approximate placement of the cameras, seen as red stars in the figure.

Initially, the idea of the thesis was focused on creating a mobile solution that could be brought into patients' homes. This was because almost all initial stroke assessments are carried out at home, but when contemplating the idea complications increased. The placement of the camera was proposed to be either in a tablet or on the paramedic. The tablet idea was discharged since it would hinder the workflow. The paramedic can not hold the tablet and film the patient at the same time as completing the assessment. A placement on the paramedic was thought to create difficulties controlling what was recorded as well as the camera being in the way and not stabilized. Images with bad quality would affect the output of the entire system negatively. Another parameter to assess was the space-consumption in the ambulance when choosing a certain placement.



**Figure 4.10:** Approximate placement of three static cameras.

An advantage of placing the cameras inside the vehicle is that there is a very limited space where the patient will be, but it also introduces difficulties. If the system is in the way, it can slow down the pace but also damage the system causing it to not work. To avoid this one camera is placed in the corner of the patient's right leg, to view the legs, and a second camera is placed on the same wall but further in inside the ambulance to view the arms. A third camera is placed in the ceiling, facing down on the patient's torso, primarily focusing on the face.

The chosen placement agrees with the placement used in previous studies of telestroke and by the simulated stroke assessments from which the demo is derived. However some trials have used two cameras instead of three, replacing the two cameras filming legs and arm with one camera filming both. Since quality is important and the simulated videos obtained and analysed contain three camera angles this layout was the one chosen. [50], [77]

### Video Analysis Hardware

The algorithms constructing the video analysis can be run on a server in the ambulance, in the hospital or in the cloud. Choosing the placement of where the heaviest calculations are completed has not been an easy choice.

Placing the server in the hospital requires transfer of the video from the ambulance to the hospital and back again after the analysis is completed. The transfer of video in rural areas is a known limitation that decreases the quality of current telestroke assessments. Until a better and more reliable connection can be assured the transfer

of data back and forwards is unnecessary. An advantage of placing the server at each hospital is the decreased amount of servers needed with capacity of completing the video analysis. Maintenance is easier and costs can be reduced if servers are placed at hospitals. Having one server for multiple calculations from different vehicles may set more demands on the server and if problems occur, all vehicles will be affected.

The same reasoning concerning disadvantages applies to the cloud based solution. A cloud based solution will allow Ortivus, or another company developing the solution to be more involved in handling and maintaining the system. Updates and service will be easier. A cloud based solution requires network connection at all times to work continuously. A cloud based solution is the best solution for the future, when the connection can be assured. Transferring the data multiple times between the mobile and stationary system can be seen as a security issue.

Placing the server, where the video analysis algorithms are run, in each vehicle is seen as the best option. The choice will ensure a stable connection and a redundant system. Since the vehicles are crowded, introducing new add-on products is not wanted. A server inside the ambulance is needed no matter if the calculations are completed in the ambulance or sent for remote analysis. However the choice of placing the server inside the ambulance requires a better and more expensive server in each car than if the calculations were completed on a remote server. Placing one server completing video analysis in every vehicle will be more expensive than including one reachable server at a hospital. Placing the server inside the ambulance makes maintenance, updates and controls harder as more units are used. The vehicles are used in care situations making maintenance hard to plan.

The servers that would be needed, depending on chosen placement, are not compared because of their different demands. The server at the hospital needs to perform calculations for more than one vehicle at a time. Wherever the server is placed the server performing the video analysis requires high demands on memory and processing power in order to complete wearing calculations.

### 4.3.3 Video Analysis

To create the suggested system in-house requires new competence, capital and a long time from idea to finished product. Advantages with building in-house are the total control over the development and keeping knowledge in the company. The organisational choices will affect the product, the company and the outcome. A suggestion is to develop the suggested system together with another company to combine strengths of both companies and decrease the level of entry. In-house development may be an option after a few years when the market is more ready, outsourcing some elements in the development of the suggested system will spread the risks.

The suggested system will be used as an augmented reality, AR, system enhancing the reality. The final system is not intended to be an AR system. The decision of including AR in the suggested system was because it allowed output from the system even if few training data were collected.

The system must safely handle high risk information. This can be compared to other high risk areas where image or video analysis is already in use. For example image analysis of faces can be used to create biometric passports and for access control in high security environments such as airports. During recent years there has been a progress in the usage of image analysis in tracking of people. The analysis can be carried out on a single person, multiple people or crowds. Crimes and unusual

behaviour as bags left at airports can be detected, practise in sports can be analysed, games can be created and rehabilitation and home activity can be controlled.

Since almost all objects in the video will be static or known, background subtraction may be an option. The background will not change much from one assessment to the next. Some extra devices may appear in the image but overall the background will be known.

By detecting landmarks the system can detect facial expressions, emotions, vital signs and the movement of different body parts.

The classification of the suggested system has been determined to be best modelled using statistical models rather than AI. This is primarily because statistical models present a result that is easy to interpret.

An advantage of an AI system is that the system can improve its decision-making the more data it gathers. Technically this is an improvement but ethically and legally this is a big restriction. Since 2017 medical software has to be CE-certified to be clinically used. However, there is no clear interpretation of the law on how to certify a system that is always improving. The goal is that every new data point should make the system better but in reality some data might introduce a worse outcome than the concluded accuracy of the system. The size of the database will have large effects on the training that can be done by the system. The more data, the better accuracy and precision the system can achieve.

If a system creates some sort of clinical decision it should give results in spans rather than in point estimations. This gives the user a wider sense of uncertainty of the decision making the user includes more of her or his knowledge for interpretation. A true diagnosis is needed when training the system to analyse how well it is doing. The combination of a clinical assessment and a system could help users to not get stuck in an initial idea of diagnosis as well as not being affected in a stressful situation.

A validation could be performed by a doctor assessing the patient in the vehicle at the same time as the system is assessing the patient. The doctor should be present in the vehicle and not through remote assessment via telemedicine, in order to create the best and most reliable comparison. If telemedicine is used for the assessment, the discussion of telestroke's validity will be a limitation to the result.

A ground truth could be determined inside the hospital. The assessment may be completed as a second or third assessment through NIHSS. The suggested system could be placed inside the hospital to create a ground truth. A disadvantage with this solution is that the assessments are not completed in a prehospital environment. An advantage is that the doctor can be present at all times, which would be too expensive and resource demanding to complete in a prehospital environment.

To have recordings of stroke assessments completed by the NIHSS will allow the validation of the suggested system retrospectively. This gives the creators of the suggested system time to analyse and understand what differs the clinician's interpretation to the system's. It would allow a comparison of one study completed solely by assessing the patient with the NIHSS and another study assessing the patient with the suggested system. Since the two studies in the comparison will include the same participants at the identical stage of the condition's progress, due to the recordings, a valid comparison could be performed.

#### 4.3.4 Quantitative Measurements

Derived from interviews and literature are quantitative stroke parameters possible to detect by video analysis. Some measurements described require guidance from a

professional in order to complete the measurement. For example testing motor skills requires the paramedic to instruct the patient to attempt to make a movement. Other parameters such as neglect might be better tested when the patient is non-aware of the test. This would make the patient act as normal. The tests included in the suggested system as well as in current stroke scales, require the patient to be cognitively active and understand instructions. The possible quantitative measurements identified are all currently tested in the NIHSS. The four derived quantitative measurements of detecting stroke included in the suggested system are:

- Eye movements
- Facial movements
- Head movements
- Extremity motor functions

The four above mentioned quantitative measurements will allow a full or partwise analysis of 11 factors included in the NIH Stroke Scale. The 11 factors are:

- Level of consciousness
- Commands
- Gaze
- Visual fields
- Facial palsy
- Left motor arm
- Right motor arm
- Left motor leg
- Right motor leg
- Ataxia
- Extinction/inattention

The remaining four out of fifteen factors included in the NIHSS are not thought to be well analysed with quantitative measurements. This is because these parameters require more than video analysis in order to be analysed correctly. The four factors are:

- Questions
- Sensory
- Language
- Dysarthria

Tracking gaze- and eye-movements could determine the gaze, visual fields and the neglect/extinction factors included in the NIHSS. The tracking could also partly detect the level of consciousness

Gaze-patterns could be used when a patient is viewing the NIHSS pictures to visualise where in the pictures the patient is looking. A disadvantage is that the screen space gaze tracking in the SDK requires calibration before start, which is time consuming. However, the function can be used online and offline for real-time assessments and recorded assessments.

Determining facial movements could detect facial paresis and create information on sensory loss, two factors that are included in the NIHSS. By detecting facial landmarks emotions can be derived. Emotions may give information on sensory deductions.

If a patient leans his/her head to one side or focus the gaze to one side stroke should be investigated. The factors are not explicitly tested in the NIHSS, but most professionals use the factors as signs to include in the final assessment and as a sign of inattention. The head movements could be detected by video analysis. [77]

Drift of extremities is included in the NIHSS. By including video analysis, tracking the legs and arms motions and a paramedic guiding the test, extremity motor functions can be monitored. If the system could detect smaller changes than a professional, analysis of Ataxia could be included in the extremity motor function test. Ataxia is often mistaken for paresis.

Testing the extremity motor functions and tracking body parts could also help analyse the commands as well as the left and right motor arm and leg functions, which are all factors included in the NIHSS.

### 4.3.5 Demo

The simulated videos of stroke assessment were combined with an EPR from Ortivus and a demo application from an SDK created by Visage Technologies in order to generate demo images. Further development using the SDK to customise the application can be done.

The demo created visualises the facial feature detection and gaze-tracking of a simulated stroke assessment in the prehospital care. The simulated assessment was completed by using telestroke following the NIH stroke scale. It was important that the simulations were completed using NIHSS in order to have recordings of a patient completing instructions of the NIHSS. The choice of stroke scale enabled the use of the suggested system. The demo can be compared to the Use Case described in Section 4.2.5. The demo and the Use Case model the same case. The demo displays the output from the system seen by the paramedic, not by the remote doctor.

Creating a demo has been an important factor in creating a human centred design. The demo has been iterated many times and it is far from finished. The demo includes the determined conceptual system and it should be used to further describe interactions with the system. The demo includes interactive parts, colour coding, and the suggested system implemented in an existing system, in this case implemented in MobiMed.

The demo enables an initial visualisation of how the system could look. Enhancing the gaze and facial features in the videos create an augmented reality pin-pointing the key identifiers in the image. The SDK used to create the demo included more parameters to be tested than the gaze and the facial landmarks. Other functions were age, gender and emotion estimations.

When visualising the demo and the flow of the system it is important to remember that in a real stroke assessment the paramedics will not triage for stroke only. Therefore the stroke assessment can not override the entire assessment, vital signs and all possible contradictory conditions have to be assessed and retained when analysing the condition. No one knows if it is stroke or another condition mimicking a stroke.

The demo can be manually started by the user if the initial assessment resulted in a positive assessment of stroke or if other stroke symptoms are present. The demo included in an EPR is shown in figure 4.11 (a)-(d). Step (a) and (b) requires the paramedic to interact with the system.

Step (a) visualises an initial stroke assessment as it is completed today. The initial stroke assessment is still needed to reduce the gap when changing from the old assessment to the suggested system. It is important to include the initial assessment because it can be completed in the patient's home. The suggested system is to be used inside the ambulance on the way to the hospital in order to make use of the time of transportation. The user starts the suggested system manually, both through the triage tab but also in the care process tab. A manual start could be completed if the signs are not positive according to FAST but a stroke is still not rule out.

Step (b) shows the triggering of the suggested system. The suggested system is triggered automatically if the initial assessment is indicating a stroke, or if started manually by the user. The triggering of the system starts with the appearance of a pop-up window instructing the paramedic to issue a stroke alarm. The paramedic is in control of the system. The first information from the system is to make the paramedic aware that the initial assessment was positive. The paramedic is asked if he or she wants to continue with an extensive assessment. If the user states "OK" the suggested system is started. Reasons for stating "Cancel" may for example be if the patient is showing other contradictory symptoms as well or if the transfer time is short.

Step (c) shows the suggested system. If the system is started manually, the first view of the system would be this page. The tests to the left are separated into three individual tests instead of one including all parameters. This was the chosen solution since time may be limited or a certain test is more interesting to the user than another. It gives freedom for the user and it also allows the user to interact with the semi-automated system. A view of the patient is shown to verify that the landmarks detected are correctly placed. If the test was extremity motor functions the view would model arms and legs instead. Since the demo regards facial feature detection the face is shown.

After step (c) the system instructs the paramedic to ask the patient to smile. When the question is asked the paramedic will approve that the patient is trying to smile and thereby continue the analysis. This makes the system interactive and demands the user of the system to continue monitoring the system. It may reduce errors as more analyses are now completed at the same time. The pop-up window and the patient smiling are not included in the report.

After the attempt of smiling the output of the system is shown in step (d). The demo visualises that the test completed is the facial movement test. The output of the system is therefore only the analysis of facial movements so far. The data is always stored internally and sent to a clinical workstation at a hospital for further analysis by an expert when the connection is reliable. The user can choose to cancel the assessment if no storage of data is needed.

ortivus SWASFT 10.52.2.3 Offline WLAN 17:45

ECG 82  
40-100

Pulse 80 < 1 min  
SpO<sub>2</sub> (on air) 98 < 1 min

**D - Disability**

**FAST**

Facial Weakness: Yes (red), No, Unable

Affected Side Face: Left (red), Right

Arm/Lea Drift: Yes, No (green), Unable

Affected Side Arm/Lea: Left, Right

Speech: Yes, No (green), Unable

Free text

**Pupil Assessment**

Pupil Assessment; Reaction Left: Yes, No (red), Sluggish

Pupil Assessment; Reaction Right: Yes, No (red), Sluggish

Pupil Assessment; Size Left: Small, Normal (green), Large

Pupil Assessment; Size Right: Small, Normal (green), Large

**STROKE POSITIVE**

Extensive Stroke Assessment  
Start test

Time: 27/4/2018 17:45

OK Cancel

ePR Messages Monitor Adu

(a) Rapid initial assessment completed by a paramedic.

ortivus SWASFT 10.52.2.3 Offline WLAN 17:45

ECG 82  
40-100

Pulse 80 < 1 min  
SpO<sub>2</sub> (on air) 98 < 1 min

**D - Disability**

**FAST**

Facial Weakness: Yes (red)

Affected Side Face: Left (red)

Arm/Lea Drift: Yes

Affected Side Arm/Lea: Left

Speech: Yes

Free text

**Pupil Assessment**

Pupil Assessment; Reaction Left: Sluggish

Pupil Assessment; Reaction Right: Sluggish

Pupil Assessment; Size Left: Normal (green)

Pupil Assessment; Size Right: Normal (green)

**STROKE POSITIVE**

Issue a stroke alarm.

Continue with extensive stroke assessment?

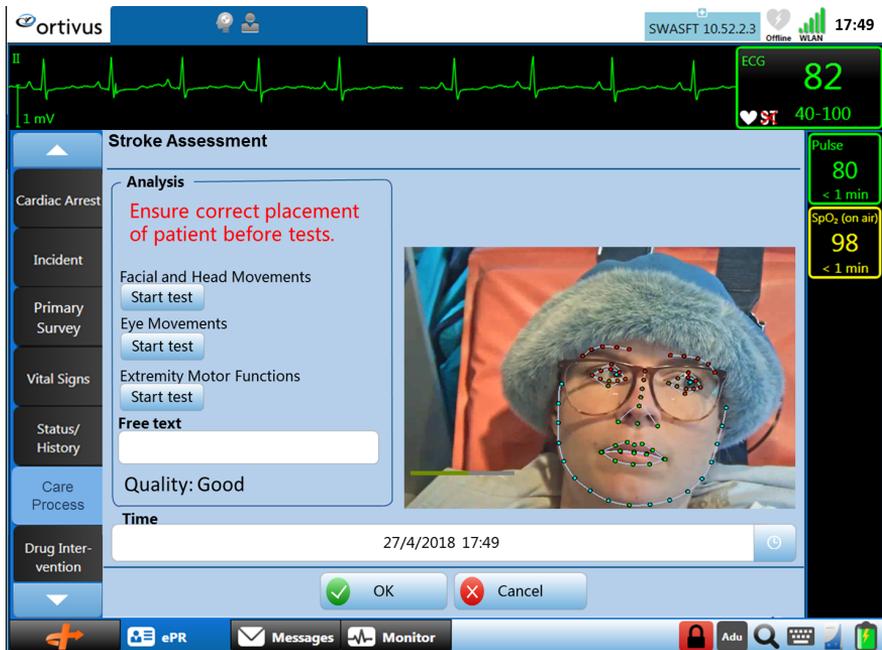
OK Cancel

Time: 27/4/2018 17:45

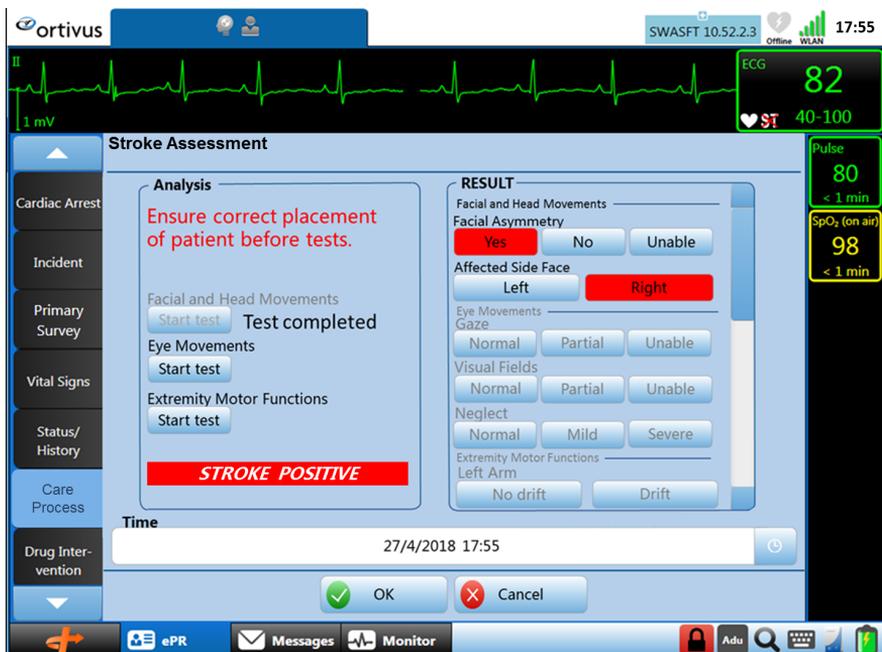
OK Cancel

ePR Messages Monitor Adu

(b) The positive initial assessment triggers the system.



(c) The start of the extensive assessment.



(d) The output of the suggested system.

Figure 4.11: The facial feature detection in the EPR demo application.

Figure 4.12 shows a close-up of the facial feature detection. The placement of the facial view camera should be reassessed as a small part of the patients chin is not seen in the image. The view of the camera depends on the movement of the patient, the strength in the patient's body to stay upright and the length of the patient. It could be desirable to allow some alterations of camera angles while the patient is placed inside the vehicle. It would allow a better outcome of the analysis.



**Figure 4.12:** The facial detection in the demo application.

It has been mentioned before that the lower muscles of the face are more affected by hemi-paresis than the upper muscles. Therefore the loss of visualisation of lower parts of the face affects the outcome of the suggested system.

A comparison of figure 4.11 (c) and figure 4.12 displays how the suggested system is occluded and affected by the patient wearing a hat. The tracking quality, visualised as a green bar in the left hand corner of figure 4.12 and 4.11 (c) is reduced by the hat. The specification of the SDK demo used describes that if the image is occluded the software uses facial symmetry to create the occluded landmarks. This affects the outcome of the system since asymmetry can not be assumed when assessing a stroke. The landmarks that are red have worse quality of detection than the ones that are green. The occlusions of the images worsen the outcome of the system. The patient should have been asked to remove both hat and glasses in order to receive a better quality of the analysis. It was not possible since test samples of videos were limited.

Figure 4.13 shows the demo when using the gaze-tracker, which was harder to visualise in a still image. The gaze-tracker shows an orange line where the person is looking. The visualisation could and should be redone to make the identification of the sign easier when implemented in reality.

The reason the alterations were not completed in the demo had to do with time-constraints, the scope of the project and the use of the software tools. The gaze-tracking was chosen to not be visualised in the demo as the facial analysis created an understanding of the system on its own. The gaze-tracking from the chosen SDK was not visualising the gaze clear enough.



**Figure 4.13:** The gaze-tracking in the demo application.

The suggested system will create an more extensive stroke assessment that is currently only completed in hospital care because of its vast amount of parameters assessed and the complexity of using it. The second assessment completed by the suggested system will achieve a second opinion, show deterioration of symptoms and support the paramedic in making a decision.



The required improvements of current stroke assessments are based on an increasing elderly population, where the over-triage accepted before is now creating too much of a burden on the system. The healthcare can no longer ensure the quality of care, therefore a novel workflow to reduce unnecessary transfers of healthy patients is required. The suggested system should contribute to safer care provided in time and give support in difficult decisions. The system should create non-tactile knowledge, resulting in an increased understanding of stroke assessment. The suggested system should decrease the DNT and record the assessment for safer work relations and teaching possibilities. The interrater variability should be decreased and resources divided more efficiently, saving suffering, time and money. The suggested system will work to create an equal care for all patients, no matter age, geographical location or condition.

There are no national guidelines determining which stroke scale to use. To determine a standard stroke scale will increase interoperability and create a common terminology which will improve the workflow as well as the quality of stroke assessment. The system must be able to handle unusual cases, for example an unstable, unconscious or amputated patient as well as remote areas etc.

A problem with the current stroke assessment is the low sensitivity, which creates an over-triage. The benefits with adding functions of the suggested system while not deducting existing functions will reduce the over-triage and thereby increase the sensitivity while not affecting the specificity. An initial stroke assessment will still be completed in the patient's home, as asked for by the paramedics.

## 5.1 Case Study

The information gathered may have been biased by the author's desires of constructing the system. To reduce the bias, interview questions were semi-structured and open to not affect the interviewees' opinions and the result was always validated by literature. The bias may have been decreased since no solution of a similar system was found. Prior studies might have led the report in another direction.

The researcher bias might have been decreased if the thesis was written by two authors rather than one. Questioning the results was instead done by the author having good communication with supervisors, other stakeholders at the company and the interviewees.

A semi-structured interview including qualitative data will never give the same answers twice. Certain questions asked have varied between the interviews although the outline has been the same. To reduce the risk of missing important data by not

asking certain questions, interviewees were always asked if they had something to add.

The interviews conducted might have introduced some sampling bias. The author was recommended the interviewees by Ortivus. Ortivus are or has been suppliers or in contact with all interviewees before which imply that the interviewees in some way all are stakeholders.

The interviewees chosen have contributed to limitations of the outcome. The outcome might depend on location, title and age of the interviewees. The results depend on certain individuals, therefore replicating the study could be hard. Since different county councils in Sweden attend to stroke care in different ways the placement of an interviewee might have given different answers even within Sweden. This has been altered for by interviewing upcoming and leading stakeholders in large geographical fluctuations in Sweden.

The author did not want to give too much information regarding the aim before meeting the interviewees. The main reason was that if video and stroke were mentioned together most people initially thought of telestroke and remote doctor communication which is a big part of the current state of the art, but it is not the idea of this system. An idea would have been to re-contact all interviewees after the first meeting to hear what they thought of the idea after some time. Two interviewees, Sjöqvist and Esbjörnsson, were contacted again seeing as they were the two interviews that gave the most new facts and inputs.

Creating a new solution can be challenging due to resilience. However, it can also be positive since nothing limits the idea, there is no known way to solve the problem. This has been one of the most challenging and rewarding parts of the thesis. Much time has been spent on research to find the best options and to evaluate all parts of the chain, from an idea to a product specification.

## 5.2 Triggering of the Suggested System

To increase the correct diagnosis of patients with strokes not possible to detect by FAST, as well as small strokes presenting few visible signs will only be possible if the suggested system is started and used. If the system is used depends on the condition of the patient and the suspicion of a stroke.

FAST is, together with the pupillary assessment, the triage completed to assess disability in all patients, no matter of a stroke indicating condition or not. As mentioned before, a triage is always completed. The suggested system could have been triggered solely by a positive stroke assessment, but instead it could be triggered both by a positive stroke assessment or chosen in the care process tab of the EPR.

It allows the user to use the suggested system even if the initial stroke assessment is negative. It is preferable since it allows the user to complete the extensive assessment even if the condition is not a large vessel occlusion. However, there is still a need to create a more precise initial assessment.

A disadvantage with the created system is that it is triggered by FAST. Relying on FAST to trigger the start of the suggested system limits the use of the new system since FAST only detects one type of stroke. Therefore the suggested system could also be triggered manually by the user. This would be completed if the initial assessment is negative but some factors present are modelling a stroke different from a large vessel occlusion. The use of the system therefore relies on the knowledge of the individual paramedic, which is not desirable.

To alter for this a new triage method for disability reductions is needed, something that is out of the scope for the thesis. Preferably the suggested system should remove all dependency of the individual knowledge of the professionals. The suggested system does this, however, since the suggested system in its turn relies on an indication or a suspicion of stroke some knowledge is still needed.

As discussed before the triage should not be prolonged since it could result in a worse outcome for the patient. Some alterations of the triage are needed to improve the stroke assessment by screening for more types of stroke.

The suggested system will decrease the over-triage, increase the knowledge of many types of stroke, ensure transfer to the correct care facility, decrease the interrater variability and support with assessment of stroke. The suggested system does not improve the outcome of the initial assessment of stroke, i.e. the triage. The user needs to find some kind of indication that it may be a stroke in order to screen for it.

This is a limitation with the method, which could not be altered for in this thesis. However, all conditions require the same thing. If it is not thought of as a possible condition it will not be screen for. The system is of big help for verification when a stroke is suspected.

The suggested system can be reached both through the triggering of a positive initial stroke assessment in the triage as well as through predetermined care processes.

### 5.3 Culture

The culture is the spirit of the organisation, it describes unwritten rules of how to act, behave and work. The culture can be hard to determine and identify, some of the cultural rules may be written down, but some are just a way of interacting and acting created by the values and beliefs of the professionals.

Culture is often set by the owners and managers of the organisation and spread down through the organisation. It is important that the change in culture comes from the upper layers of the organisation or that the upper layer of the organisation sees the need for change in culture. If the top management shows commitment to the change, the change will most likely spread down through the organisation. The top management can implement the actual change.

The culture of the healthcare sector and especially stroke assessment has been identified as largely dependent on the individual knowledge of healthcare professionals. The knowledge is created from the use of qualitative rather than quantitative data, resulting in a high interrater variability. The professionals are educated differently depending on teachers. The education and the skills developed are difficult to update since it will imply an initial decrease in knowledge. Tactile knowledge is knowledge spread from person to person. The tactile knowledge is large when describing stroke assessment, which might explain why stroke assessment is thought of as hard. To structure problems connected to stroke scales and the culture was hard because the knowledge was primary tactile.

### 5.4 Automation of Human Interaction

Healthcare is a sector that has long relied on the competence and skills of the workers, making users reluctant to automation. The suggested system would lead to a semi-automated system, but it is important to understand that it is not created to

replace the human interaction or the human mind. Three ironies of automation are mentioned as possible losses when introducing an automatic system. [78]

The system and the developers of the system will introduce new risks. Implementing the system in a restricted sector, as the healthcare, will force extensive testing of functions for validation before approval.

Non-automated functions are left by the system-developer for the human to solve. Some difficult functions are left undeveloped since the system can not handle the task well enough. The system-developer is both eliminating work tasks and relying on the user for the system to work.

The more reliable the system is the fewer risks and the lower the accident rate. The user receives less training in using the system and solving problems, which will lead to decreased knowledge of the system.

It is hard to change work ethics and culture in any skilled company. The risks of creating a semi-automated system should be included in the building of the system to reduce hazards. Advantages of the suggested system are enabling focus on multiple parameters at the same time and assessment of patients for a longer time, which will increase the information outcome.

## 5.5 Sustainable Development

Sustainable development is development that meets the current need without jeopardizing the future generation's ability to meet the needs. Sustainable development is focused on economic, environmental and social development.

In general, an increasing economic development must not affect the environmental or social development negatively. For the suggested system the economic development may regard the decrease in geographical fluctuations. The environmental development regards economizing materials and choosing sustainable power consumption. No actual materials or products have been chosen for the implementation of the system, but it will be an important stand-point to take further along in the project. The social development concerns equality, empowerment and human rights. This can be compared to the system contributing with a lower interrater variability resulting in a more equal and patient-oriented care.

## 5.6 Ethical Aspects

Validation of a system is a critical ethical aspect. Validation determines if the system creates more benefit than it causes harm, a term called non-maleficence. [79]

A system must not introduce more harm than if not used. For example if the suggested system determines a true stroke patient as healthy more harm may be introduced than if the system was not used. Validation will ensure a safe and evidence-based system.

Everyone has the right to refuse care, this is called autonomy. Autonomy causes an ethical conflict regarding non-maleficence, but it increases the patient's self-control. A patient can refuse to be monitored by the camera. No one can force him/her to approve care, but the result might be a lower quality of care. If the patient can be viewed as making bad decisions because of the condition, a relative that knows the patients choice before becoming ill will make the decisions. If a decision can not be made, the professionals will choose the decision most beneficial for the patient.

The paramedics and other healthcare professionals make decisions regarding others' health on a regular basis. This is burdening and it might affect the work but also their psychological wellness. Justice and equality must be created by achieving the same treatment with non-geographical fluctuations. A monitoring system could intrude the patients' and professionals' private space.

## 5.7 Legal Restrictions

Legal aspects limit the innovation in the healthcare sector, which is a safety for the professionals and the patients. Legislation should not hinder innovation but it will slow it down to ensure safety, validation and an evidence based care. Complications with creating the suggested system which are both legal and technical are the transfer, storage and receiving of data.

Recording videos require all participating parts to agree with the video being used according to the GDPR and the Patient Data Act. The data collected by the surveillance cameras has to be encrypted. The safety also concerns a stable system that can be distributed and used equally. No one should be harmed in the testing and validation of the product, in this case implying the system must make the correct assessment. The testing includes written consent by the patient and sensitive and private data must be handled with care.

## 5.8 Drift from Initial Idea

The project has changed a lot during the span of the thesis. The initial idea was to not include doctors in the system, to make the suggested system mobile and to create a system that could give direct decision support to the user. Along the process of the thesis this has been altered due to reasons already discussed. It is now seen as highly important to not remove the doctors' competence and to start off by making an augmented reality system placed inside the vehicle, rather than a decision system.

## 5.9 Future Work

The suggested system is sought for by users and it is possible to create a solution that could be tested in clinical trials. The next step is to create a system adapted and implemented in an EPR as well as customising the video analysis. There could be other areas of use for the system such as the in-house healthcare, health centres and remote care facilities.



A growing and an aging population require better resources for accurate stroke assessment. The suggested system is an intelligent vision based system for assessment of stroke. Four quantitative measurements of stroke assessment through video analysis have been determined and discussed.

Novel solutions of video analysis are covered which will reduce the interrater variability and the over-triage. These improvements will enhance the quality of stroke assessment and thereby the outcome of stroke. Suggestions of software and hardware solutions as well as implementations are given. The system is visualised in an EPR to create an understanding of how it should be used and how the solution can be combined with current knowledge in the area.

Limitations are still present but the healthcare expresses a need for an improvement of prehospital stroke assessment. It is technically possible to create the suggested system and the solution follows the market evolution.



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## Bibliography

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- [1] Levin, L Å., Brogårdh, C. et al. (2017) *Nationella riktlinjer för vård vid stroke*, Socialstyrelsen [Online] Available at: (<https://www.socialstyrelsen.se/Lists/Artikelkatalog/Attachments/20618/2017-5-13.pdf>) [Retrieved 1 Feb. 2018]
- [2] Riksstroke (2017) *Stroke och TIA - Slutgiltig årsrapport från Riksstroke*, Riksstroke; [Online] Available at: ([http://www.riksstroke.org/wp-content/uploads/2017/07/Riksstroke%C3%85rsrapport2016\\_slutversion.pdf](http://www.riksstroke.org/wp-content/uploads/2017/07/Riksstroke%C3%85rsrapport2016_slutversion.pdf)) [Retrieved 22 Jan. 2018]
- [3] Jauch, E C. (2018) *Ischemic Stroke Treatment & Management*, MedScape; [Online] Available at: (<https://emedicine.medscape.com/article/1916852-treatment>) [Retrieved 2 Feb. 2018]
- [4] Saver, J. (2006) *Time Is Brain — Quantified*, American Stroke Association, January 2006, Volume 37, Issue 1; [Online] Available at: (<http://stroke.ahajournals.org/content/37/1/263.full>) [Retrieved 1 Feb. 2018]
- [5] Riksstroke (2017) *Information om stroke*, Riksstroke – the Swedish Stroke Register; [Online] Available at: (<http://www.riksstroke.org/sve/patient-och-narstaende/stroke/>) [Retrieved 15 Jan. 2018]
- [6] National Stroke Association (2018) *Post-Stroke Conditions*, National Stroke Association [Online] Available at: (<http://www.stroke.org/we-can-help/survivors/stroke-recovery/post-stroke-conditions>) [Retrieved 2 Feb. 2018]
- [7] Jia, J., Band, R. et al. (2017) *Accuracy of Emergency Medical Services Dispatcher and Crew Diagnosis of Stroke in Clinical Practice*, *Frontiers in Neurology*, NCBI, Volume 8 [Online] Available at: (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5603652/#B9>) [Retrieved 7 Feb. 2018]
- [8] Gropen, T I., Gokaldas, R. et al. (2014) *Factors related to the sensitivity of emergency medical service impression of stroke*, *Prehospital Emergency Care*, NCBI, Volume 18, Issue 3, pp. 387-392 [Online] Available at: (<https://www.ncbi.nlm.nih.gov/pubmed/24460036>) [Retrieved 7 Feb. 2018]
- [9] Fothergill, R. T., Williams, J. et al. (2013) *Does Use of the Recognition of Stroke In the Emergency Room Stroke Assessment Tool Enhance Stroke Recognition by Ambulance Clinicians?*, *Stroke*, October 2013, Volume 44, Issue 11, pp. 3007-3012 [Online] Available at: (<http://stroke.ahajournals.org/content/44/11/3007.long#T1>) [Retrieved 21 March 2018]

- [10] Purruker, J C., Hametner, C. et al. (2014) *Comparison of stroke recognition and stroke severity scores for stroke detection in a single cohort*, Journal of Neurology, Neurosurgery and Psychiatry, Volume 86, pp. 1021–1028 [Online] Available at: (<http://jnnp.bmj.com/content/jnnp/86/9/1021.full.pdf>) [Retrieved 21 March 2018]
- [11] Kasner, S E. (2006) *Clinical Interpretation and Use of Stroke Scales*, Comprehensive Stroke Centre, Department of Neurology, University of Pennsylvania, The Lancet Neurology, Volume 5, Issue 7, pp. 603-612 [Online] Available at: ([https://www.thelancet.com/journals/laneur/article/PIIS1474-4422\(06\)70495-1/fulltext](https://www.thelancet.com/journals/laneur/article/PIIS1474-4422(06)70495-1/fulltext)) [Retrieved 12 Dec. 2017]
- [12] Harbison, J., Hossain, O. et al. (2003) *Diagnostic Accuracy of Stroke Referrals From Primary Care, Emergency Room Physicians, and Ambulance Staff Using the Face Arm Speech Test*, Stroke, January 2003, Volume 34, Issue 1; [Online] Available at: (<http://stroke.ahajournals.org/content/34/1/71>) [Retrieved 1 Feb. 2018]
- [13] Stroke - Riksförbundet (2016) *Stroke - Propp eller blödning i hjärnan*, Stroke - Riksförbundet, Sweden; [Online] Available at: (<http://www.strokeforbundet.se/show.asp?si=567&back=ja&sp=528&go=STARTSIDA-2016>) [Retrieved 16 Jan. 2018]
- [14] National Stroke Association (2018) *Act FAST*, National Stroke Association, USA; [Online] Available at: (<http://www.stroke.org/understand-stroke/recognizing-stroke/act-fast>) [Retrieved 16 Jan. 2018]
- [15] Higashida, R., Alberts, M J. et al. (2013) *Interactions Within Stroke Systems of Care - A Policy Statement From the American Heart Association/American Stroke Association*, American Stroke Association, October 2013, Volume 44, Issue 10; [Online] Available at: ([http://stroke.ahajournals.org/content/44/10/2961?ijkey=13169f40eb15c2f61df7f28739f5a223ccc01e7e&keytype2=tf\\_ipsecsha](http://stroke.ahajournals.org/content/44/10/2961?ijkey=13169f40eb15c2f61df7f28739f5a223ccc01e7e&keytype2=tf_ipsecsha)) [Retrieved 1 Feb. 2018]
- [16] National Institute of Neurological Disorders and Stroke (2016) *NIH Stroke Scale*, National Institute of Neurological Disorders and Stroke, USA; [Online] Available at: ([https://www.ninds.nih.gov/sites/default/files/NIH\\_Stroke\\_Scale\\_Booklet.pdf](https://www.ninds.nih.gov/sites/default/files/NIH_Stroke_Scale_Booklet.pdf)) [Retrieved 23 Jan. 2018]
- [17] Andsberg, G., Esbjörnsson, M. et al. (2017) *PreHospital Ambulance Stroke Test - pilot study of a novel stroke test*, Scandinavian Journal of Trauma, Resuscitation and Emergency Medicine Volume 25, Issue 37, Sweden [Online] Available at: (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5387291/>) [Retrieved 23 Jan. 2018]
- [18] Powers, W J., Rabinstein, A A. et al. (2018) *2018 Guidelines for the Early Management of Patients With Acute Ischemic Stroke: A Guideline for Healthcare Professionals From the American Heart Association/American Stroke Association*, American Stroke Association, February 2018, Volume 49, Issue 2; [Online] Available at: (<http://stroke.ahajournals.org/content/early/2018/01/23/STR.0000000000000158>) [Retrieved 1 Feb. 2018]
- [19] Kurland, D B., Khaladj-Ghom, A. et al. (2016) *Complications Associated with Decompressive Craniectomy: A Systematic Review*, National Institutes of

- Health, NCBI, USA; [Online] Available at: (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC4704457/>) [Retrieved 8 Mar. 2018]
- [20] Avgerinos, E. (2017) *Thrombolytic Therapy*, Society for Vascular Diseases, USA; [Online] Available at: (<https://vascular.org/patient-resources/vascular-treatments/thrombolytic-therapy>) [Retrieved 19 Jan. 2018]
- [21] Vascular Speciality Center (2017) *Understanding Thrombectomy and Embolectomy*, Vascular Speciality Center, USA; [Online] Available at: (<https://brvsc.com/thrombectomy-and-embolectomy/>) [Retrieved 19 Jan. 2018]
- [22] Novitzke, J. (2009) *A Patient Guide to Brain Stent Placement*, National Institutes of Health, NCBI, USA; [Online] Available at: (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3317336/>) [Retrieved 19 Jan. 2018]
- [23] Raychev, R., Saver, J L. (2012) *Mechanical thrombectomy devices for treatment of stroke*, National Institutes of Health, NCBI, USA; [Online] Available at: (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3613201/>) [Retrieved 2 Feb. 2018]
- [24] Evans, M R B., White, P. et al. (2017) *Revolution in acute ischaemic stroke care: a practical guide to mechanical thrombectomy*, BMJ Journals, Volume 17, Issue 4, England; [Online] Available at: (<http://pn.bmj.com/content/17/4/252>) [Retrieved 2 Feb. 2018]
- [25] Mayo Foundation for Medical Education and Research (2018) *Hemorrhagic stroke*, Mayo Foundation for Medical Education and Research, USA; [Online] Available at: (<https://www.mayoclinic.org/diseases-conditions/stroke/diagnosis-treatment/drc-20350119>) [Retrieved 19 Jan. 2018]
- [26] Hosseini-zhad, M., Sohrabnejad, R. (2017) *Stroke mimics in patients with clinical signs of stroke*, National Institutes of Health, NCBI, USA; [Online] Available at: (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5596193/>) [Retrieved 2 Feb. 2018]
- [27] Lazarony, L. (2015) *Common Misdiagnoses for Stroke*, StrokeSmart, National Stroke Association; [Online] Available at: (<http://www.strokesmart.org/misdiagnosis-for-stroke>) [Retrieved 2 Feb. 2018]
- [28] Stroke Center (1999) *Blood Vessels of the Brain*, The Internet Stroke Centre, USA [Online] Available at: (<http://www.strokecenter.org/professionals/brain-anatomy/blood-vessels-of-the-brain/>) [Retrieved 2 Feb. 2018]
- [29] Tocco, S. (2011) *Identify the vessel, recognize the stroke*, American Nurse Association, Volume 6, Issue 9, USA [Online] Available at: (<https://www.americannursetoday.com/identify-the-vessel-recognize-the-stroke/>) [Retrieved 2 Feb. 2018]
- [30] Audebert, H J., Saver, J L. et al. (2013) *Prehospital Stroke Care*, Neurology, NCBI, Volume 81, Issue 5, pp. 501-508, USA [Online] Available at: (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3776535/>) [Retrieved 2 Feb. 2018]
- [31] Hill, P. (2012) *Ambulanssjuksköterskans bedömning av strokepatient - Ambulanssjukvård*, Sophia Hemmet Högskola, Sweden [Online] Available at: (<http://www.diva-portal.org/smash/get/diva2:534935/FULLTEXT02>) [Retrieved 30 Jan. 2018]

- [32] Independent Ambulance Association (2013) *The vital link Why the NHS needs a strong independent ambulance sector*, Independent Ambulance Association, UK [Online] Available at: (<http://www.iaauk.org/docs/Thevitallink1.1.pdf>) [Retrieved 30 Jan. 2018]
- [33] Pratt, F D., Katz, S. et al. (2007) *The Role of the United States Fire Service in Delivery and Coordination*, International Association of Fire Fighters; [Online] Available at: ([http://www.iaff.org/paramedicine/Prehospital\\_EMS.pdf](http://www.iaff.org/paramedicine/Prehospital_EMS.pdf)) [Retrieved 30 Jan. 2018]
- [34] Karolinska Insitutitet (2018) *Sjuksköterskeprogrammet*, Karolinska Insitutitet, Sweden [Online] Available at: (<https://ki.se/utbildning/1sj17-sjukskoterskeprogrammet>) [Retrieved 30 Jan. 2018]
- [35] Karolinska Insitutitet (2018) *Specialistutbildningar för sjuksköterskor*, Karolinska Insitutitet, Sweden [Online] Available at: (<https://ki.se/utbildning/specialistutbildningar-for-sjukskoterskor>) [Retrieved 30 Jan. 2018]
- [36] Acker, J E., Pancioli, A M. et al. (2007) *Implementation Strategies for Emergency Medical Services Within Stroke Systems of Care*, American Stroke Association, October 2007, Volume 38, pp. 3097-3115; [Online] Available at: (<http://stroke.ahajournals.org/content/38/11/3097.long>) [Retrieved 21 Feb. 2018]
- [37] Brott, T., Adams, HP. et al. (1989) *Measurements of acute cerebral infarction: a clinical examination scale*, National Institutes of Health, NCBI, USA, July 1989, Volume 20, Issue 7, pp.864-870; [Online] Available at: (<https://www.ncbi.nlm.nih.gov/pubmed/2749846>) [Retrieved 21 Feb. 2018]
- [38] Europeiska kommissionen (2017) *Digitaliseringen av hälso- och sjukvården i EU*, Europeiska kommissionen; [Online] Available at: ([https://ec.europa.eu/info/consultations/public-consultation-transformation-health-and-care-digital-single-market\\_sv](https://ec.europa.eu/info/consultations/public-consultation-transformation-health-and-care-digital-single-market_sv)) [Retrieved 16 Jan. 2018]
- [39] Regeringen (2016) *Vision e-hälsa 2025*, Regeringen; [Online] Available at: (<http://www.regeringen.se/4a1f04/contentassets/79df147f5b194554bf401dd88e89b791/vision-e-halsa-2025.pdf>) [Retrieved 16 Jan. 2018]
- [40] Ronchi, E. (2010) *Information and Communication Technologies in Health Systems- Case studies*, Organisation for Economic Co-operation and Development; [Online] Available at: (<http://www.oecd.org/els/health-systems/informationandcommunicationtechnologiesictsinhealthsystems-casestudies.htm>) [Retrieved 16 Jan. 2018]
- [41] Kulkarni, A., Sathe, S. (2014) *Healthcare applications of the Internet of Things: A Review*, International Journal of Computer Science and Information Technologies, Volume 5, pp.6229-6232; [Online] Available at: (<http://citeseerx.ist.psu.edu/viewdoc/download?doi=10.1.1.659.5696&rep=rep1&type=pdf>) [Retrieved 16 Jan. 2018]
- [42] Doupi, P., Renko, E. et al. (2010) *E-health Strategies; Country Brief Sweden - Legal and regulatory facilitators*, European Commission, DG Information Society and Media, ICT for Health Unit, Belgium/Germany; [Online] Available at: ([http://ehealth-strategies.eu/database/documents/Sweden\\_CountryBrief\\_eHStrategies.pdf](http://ehealth-strategies.eu/database/documents/Sweden_CountryBrief_eHStrategies.pdf)) [Retrieved 19 Jan. 2018]

- [43] EUGDPR.org (2018) *GDPR Key Changes*, GDPR.org; [Online] Available at: (<https://www.eugdpr.org/key-changes.html>) [Retrieved 11 April 2018]
- [44] Regeringen (2002) *Förutsättningar för telemedicin/televård för förnyelse av vården*, Vård i tiden, Regeringen, Part 2, Chapter 13; [Online] Available at: (<http://www.regeringen.se/49bbc2/contentassets/4e38084ba44f4258b22808abdd8e50bc/del-2-t.o.m.-kap.-17-var-d-itiden>) [Retrieved 2 Feb. 2018]
- [45] Ortivus (2016) *Solutions for Modern Emergency Medical Care*, Ortivus, Danderyd, Sweden; [Online] Available at: (<http://www.ortivus.com/?noredirect=true>) [Retrieved 16 Jan. 2018]
- [46] Rogers, Y., Sharp, H. et al. (2011), *Interaction Design: Beyond Human-Computer Interaction*, John Wiley & Sons Ltd, Chichester, USA
- [47] Arvola, M. (2014) *Interaktionsdesign och UX*, Studentlitteratur, Lund, Sweden
- [48] Demaerschalk, B M., Berg, J. et al. (2017) *Telemedicine and e-Health*, American Telemedicine Association: Telestroke Guidelines, Volume 23, Issue 5, pp. 376-389; [Online] Available at: (<https://doi.org/10.1089/tmj.2017.0006>) [Retrieved 19 Jan. 2018]
- [49] Nguyen-Huynh, M N., Klingman, J G. et al. (2017) *Novel Telestroke Program Improves Thrombolysis for Acute Stroke Across 21 Hospitals of an Integrated Healthcare System*, American Stroke Association, January 2018, Volume 49, Issue 1; [Online] Available at: (<http://stroke.ahajournals.org/content/49/1/133>) [Retrieved 1 Feb. 2018]
- [50] Lindholmen Science Park (2017) *ViPHS – Videostöd i den PreHospitala Strokekedjan*, PICTA, Gothenburg, Sweden; [Online] Available at: (<https://picta.lindholmen.se/node/40131>) [Retrieved 16 Jan. 2018]
- [51] Butler, A., Runge, A. (2017) *SATCARE - REAL-TIME REMOTE DIAGNOSIS THROUGH IN-AMBULANCE TELEMEDICINE WITH BROAD-BAND SATELLITE CONNECTIVITY*, European Space Agency – Business Applications; [Online] Available at: (<https://business.esa.int/projects/satcare>) [Retrieved 19 Jan. 2018]
- [52] Walter, S., Kostopoulos, P. et al. (2010) *Bringing the Hospital to the Patient: First Treatment of Stroke Patients at the Emergency Site*, Plos One, 2010, Volume 5, Issue 10; [Online] Available at: (<http://journals.plos.org/plosone/article/file?id=10.1371/journal.pone.0013758&type=printable>) [Retrieved 6 Feb. 2018]
- [53] Bowry, R., Parker, S. et al. (2015) *Benefits of Stroke Treatment Using a Mobile Stroke Unit Compared With Standard Management*, American Stroke Association, October 2015, Volume 46, pp. 3370-3374; [Online] Available at: (<http://stroke.ahajournals.org/content/strokeaha/46/12/3370.full.pdf>) [Retrieved 6 Feb. 2018]
- [54] Fargen, K M., Jauch, E. et al. (2015) *Needed Dialog-Regionalization of Stroke Systems of Care Along the Trauma Model*, American Stroke Association, June 2015, Volume 46, Issue 6; [Online] Available at: (<http://stroke.ahajournals.org/content/46/6/1719.full>) [Retrieved 1 Feb. 2018]

- [55] Oxehealth (2018) *Technology*, Oxehealth; [Online] Available at: (<http://www.oxehealth.com/>) [Retrieved 28 Feb. 2018]
- [56] Boardley, A. (2017) *Now you see it: Oxehealth wins prestigious Academy Award*, Royal Academy of Engineering; [Online] Available at: (<https://www.raeng.org.uk/news/news-releases/2017/august/now-you-see-it-oxehealth-wins-prestigious-academy>) [Retrieved 28 Feb. 2018]
- [57] Faiz, K W., Sundseth, A. et al. (2013) *Prehospital delay in acute stroke and TIA*, *Emergency Medical Journal* 2013, Issue 30, pp. 669-674.; [Online] Available at: (<http://emj.bmj.com/content/30/8/669>) [Retrieved 1 Feb. 2018]
- [58] Bengtsson, K. (2018) *Metrics Solutions, Technical Sales Sensor, Vision and ID*, Interview, Ortivus, Sweden, 18 Jan. 2018
- [59] Ke, S-R., Thuc, H L U. et al. (2013) *A Review on Video-Based Human Activity Recognition*, *Computers*, 2013, Volume 2, pp. 88-131; [Online] Available at: (<http://www.mdpi.com/2073-431X/2/2/88/htm#B33-computers-02-00088>) [Retrieved 5 Feb. 2018]
- [60] Giovanoli, P., Tzou, C H J. et al. (2003) *Three-dimensional video-analysis of facial movements in healthy volunteers*, *Journal of Plastic, Reconstructive & Aesthetic Surgery*, Volume 56, Issue 7, pp. 644-652; [Online] Available at: ([http://www.jprasurg.com/article/S0007-1226\(03\)00277-7/fulltext](http://www.jprasurg.com/article/S0007-1226(03)00277-7/fulltext)) [Retrieved 20 Feb. 2018]
- [61] Salmaso, L., Brombin, C. (2013) *Permutation Tests in Shape Analysis*, Springer Science and Business, New York, USA, pp. 3-6
- [62] Agrawal, A., Menzies, T. (2018) *Is “Better Data” Better Than “Better Data Miners”?*, *International Conference of Software Engineering*; [Online] Available at: (<https://arxiv.org/pdf/1705.03697.pdf>) [Retrieved 3 April 2018]
- [63] Wallgren, U., Bohm, K. et al. (2017) *Presentations of adult septic patients in the prehospital setting as recorded by emergency medical services: a mixed methods analysis*, *Scandinavian Journal of Trauma, NCBI*, March 2017, Volume 23; [Online] Available at: (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC5439232/>) [Retrieved 25 Feb. 2018]
- [64] Rajendran, K. (2017) *Data Mining Techniques in Diagnosis of Chronic Diseases*, *Journal of Applied Technology and Innovation*, Volume 1, Issue 2, pp.13-40; [Online] Available at: ([https://www.apu.edu.my/ejournals/jati/journal/JATI-VOLUME\\_1-ISSUE\\_2-2017.pdf](https://www.apu.edu.my/ejournals/jati/journal/JATI-VOLUME_1-ISSUE_2-2017.pdf)) [Retrieved 6 April 2018]
- [65] Rubin, G D., Roos, J E. et al. (2015) *Characterizing Search, Recognition, and Decision in the Detection of Lung Nodules on CT Scans: Elucidation with Eye Tracking*, *Radiology, RSNA*, Volume 274, Issue 1; [Online] Available at: (<https://pubs.rsna.org/doi/full/10.1148/radiol.14132918>) [Retrieved 6 April 2018]
- [66] Llorens Rodríguez, R., Noe, E. (2016) *Through the Eyes of Neglect Patients: A Preliminary Eye-Tracking Study of Unilateral Spatial Neglect*, *Journal of Neuropsychiatry and Clinical Neurosciences*, Volume 28, pp.8-9; [Online] Available at: (<https://riunet.upv.es/bitstream/handle/10251/82409/s1-1n214380331656975785.pdf?sequence=2&isAllowed=y>) [Retrieved 6 April 2018]

- [67] Scimmel, M., Christou, P. et al. (2009) *Distances between facial landmarks can be measured accurately with a new digital 3-dimensional video system*, American Association of Orthodontists; [Online] Available at: (<http://smarteye.se/wp-content/uploads/2015/01/Schimmel-et-al..pdf>) [Retrieved 27 Feb. 2018]
- [68] Schimmel, M., Leemann, B. et al. (2011) *Quantitative assessment of facial muscle impairment in patients with hemispheric stroke*, Journal of Oral Rehabilitation, NCBI, Volume 38, pp. 800-809; [Online] Available at: (<https://www.ncbi.nlm.nih.gov/pubmed/21428990>) [Retrieved 27 Feb. 2018]
- [69] Andrews, A W., Bohannon, R. (2000) *Distribution of muscle strength impairments following stroke*, Sage Journals; [Online] Available at: (<http://journals.sagepub.com/doi/pdf/10.1191/026921500673950113>) [Retrieved 27 Feb. 2018]
- [70] Schimmel, M., Leemann, B. et al. (2010) *Masticatory Function and Bite Force in Stroke Patients*, Journal of Oral Rehabilitation, Sage Journals, Volume 90, Issue 2; [Online] Available at: (<http://journals.sagepub.com/doi/abs/10.1177/0022034510383860>) [Retrieved 28 Feb. 2018]
- [71] Roffe, C. (2002) *Hypoxia and Stroke*, Age and Ageing, Volume 31; [Online] Available at: ([https://academic.oup.com/ageing/article-pdf/31/suppl\\_2/10/86129/310010.pdf](https://academic.oup.com/ageing/article-pdf/31/suppl_2/10/86129/310010.pdf)) [Retrieved 6 April 2018]
- [72] Wolf, S L., Butler, A J. et al. (2013) *Contemporary linkages between EMG, kinetics and stroke rehabilitation*, Journal of Electromyography and Kinesiology, Volume 15, Issue 3, pp.229-239; [Online] Available at: (<https://www.ncbi.nlm.nih.gov/pmc/articles/PMC3572513/>) [Retrieved 6 April 2018]
- [73] Sjöqvist, B-A. (2018) *Professor of practice in Healthcare Informatics*, Chalmers, Interview, Stockholm, Sweden, 17 Jan. 2018
- [74] Wretman, F. (2018) *Paramedic*, Interview, Västerås Hospital, Sweden, 24 Jan. 2018
- [75] Carlsson, M. (2018) *Paramedic*, Interview, Västerås Hospital, Sweden, 24 Jan. 2018
- [76] Rooth, E. (2018) *Chief Physician in Internal Medicine, Process Owner Stroke*, Interview, Danderyd's Hospital, Stockholm, Sweden, 30 Jan. 2018
- [77] Esbjörnsson, M. (2018) *Chief Physician in Neurology and Internal Medicine*, Interview, Hässleholm's Hospital, Sweden, 13 Feb. 2018
- [78] Bainbridge, L. (1983) *Ironies of Automation*, Automatica, Volume 19, Issue 6, pp. 775-779; [Online] Available at: ([https://www.ise.ncsu.edu/wp-content/uploads/2017/02/Bainbridge\\_1983\\_Automatica.pdf](https://www.ise.ncsu.edu/wp-content/uploads/2017/02/Bainbridge_1983_Automatica.pdf)) [Retrieved 6 Feb. 2018]
- [79] Summers, J., Morrison, E E. (2009) *Principles of Healthcare Ethics*, Health Care Ethics: Critical Issues for the 21st Century, Jones and Bartlett Publishers, Sudbury, MA, Chapter 2; [Online] Available at: (<http://samples.jbpub.com/9781449665357/Chapter2.pdf>) [Retrieved 9 Feb. 2018]
- [80] Robson, C. (2002) *Real World Research*, 2nd edition, Blackwell Publishing, Oxford, UK



# Appendices



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## Semi-Structured Interview Questions

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### A.1 Interview with Expert in Telestroke

What limits the current stroke assessment?

What is the most important criteria for efficient stroke assessment?

How could stroke assessment be more efficiently carried out?

Is there a reason why current systems focus on video communication rather than video analysis?

What are the difficulties of applying video analysis in stroke assessment?

Are there any known hardware criteria for similar solutions?

What aspects of video based stroke assessment are most important to study?

What do you think the future holds for stroke assessment in the prehospital care?

### A.2 Interview with Paramedics

How is an assessment of stroke completed in the prehospital care?

Which stroke scale is used?

Are there other measurements except from those included in the stroke scale and vital signs that are of importance?

Where does an initial assessment usually take place?

What are the limitations and the challenges with the current way of assessing a stroke?

How could a system support the paramedic in a stroke assessment?

What is the biggest challenge with including a semi-automatic system for the assessment of stroke?

What do you think the future holds for stroke assessment in the prehospital care?

### A.3 Interview with On-Call Doctor

How is an assessment of stroke completed?

Which stroke scale is used?

Are there other measurements except from those included in the stroke scale and vital signs that are of importance?

Would it be possible to quantify the signs of stroke?

Is there a limit where all clinicians agree on a diagnosis?

Does the verdict differ depending on if a neurologist or another professional assess the patient?

What are the limitations and the challenges with the current way of assessing a stroke?

How could a system give support in a stroke assessment?

What is the biggest challenge with including a semi-automatic system for the assessment of stroke?

What do you think the future holds for stroke assessment in the prehospital care?

#### A.4 Interview with Creator of a Prehospital Stroke Scale

What problems does the stroke scale preHAST solve?

Is there any part of the implementation of the telestroke system that was hard to predict the outcome of?

What positive and negative effects has the telestroke-solution had?

Has the system been approved/liked by doctors, patients and nurses?

What is included in the telestroke solution? Hardware, assessment support etc.?

What functions are sought after by the users?

Are there symptoms/factors hard to notice through video-link and how are the problems solved?

In what way does the video-link improve prehospital stroke assessment?

What rules and legislations have been important during the process?

#### A.5 Interview Regarding Cameras and Video Analysis

What solutions are on the market today?

Do you know of any solutions implemented in the healthcare sector?

What will be most important for the quality of the system?

Do you see any disadvantages or limitations that could affect the outcome of the system?

What functions in the camera would be needed?

How precise is the data from the camera?

How expensive are the solutions found on the market today?

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## Protocol for Observations

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The observations concerned studying the environment inside an ambulance. The author did not study a live stroke assessment, but was instead showed one when visiting the ambulance unit in Västerås. The observations were semi-direct and carried out after asking how an initial stroke assessment is currently done. The author studied the inside of an ambulance to understand the area, other instruments used and to get an understanding of where the placement of the cameras, if placed inside the ambulance could be done.

To complete the semi-direct observations in the field the author chose to work with a structure giving a more detailed framework. [80, pp. 309-344]  
The activities observed were:

**Space:** What is the physical space like and how is it laid out?

**Actors:** What are the names and relevant details of the people involved?

**Activities:** What are the actors doing and why?

**Objects:** What physical objects are present?

**Acts:** What are specific individual actions?

**Events:** Is what you observe a part of a special event?

**Time:** What is the sequence of events?

**Goals:** What are the actors trying to accomplish?

**Feelings:** What is the mood of the group and of individuals?

The author found that the observations regarding the factors of space, actors, activities, feelings and objects were of most importance. The aim was not to test a new solution but to discover and identify the overall work that takes place in an ambulance when a stroke assessment is performed. Therefore no special events happened resulting in the parameters of acts, events, time and goal being less important at this stage of the observations. The list of observed activities was narrowed down to:

**Person:** Who is using the technology at any particular time?

**Place:** Where are they using it?

**Thing:** What are they doing with it?



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## Description of Visage Technologies' SDK

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A software developing kit, SDK, from Visage Technologies has been used to create the demo. The used software in the SDK was simply the demo of the SDK showing how it could be used. No actual software development has taken place.

The SDK uses a range of computer vision techniques to create the demo. The SDK is based on MPEG-4 which is a standard, ISO 14496, describing Face and Body Animation, FBA. FBA includes a set of facial actions, e.g. emotions and well defined body and facial landmarks.

Defined distances in the MPEG-4 between key facial feature points derive emotions. This is used in the SDK. The MPEG-4 contains over 70 facial landmarks. If interpolation is needed to find an estimate for a facial landmark left and right symmetry is assumed, which may interfere with the result wanted if a person is experiencing a stroke. The SDK can handle occlusion in the image, meaning that some part of the image is temporarily or fully hidden or covered.

Two of the functions from the SDK used in the demo for the suggested system will be explained in more detail. The two functions are Facial Feature Tracking and Gaze Tracking.

### C.1 Facial Feature Tracking

Since the demo of the suggested system displays a video, tracking of facial features has been used. The tracking involves facial features, expressions, head poses, gaze information, eye closure, facial feature points and estimation of 3D models of the face.

To reduce the noise and the delay in the video smoothing is completed. A reference point between the eyes is used for alignment. Static parameters of the face that are specific for an individual, so called shape units, are used to realign the image after a loss of contact. By using the key facial feature points the face can be detected in the image. A square facial bounding box is put around the verified face to segment it from the background.

The image is internally converted into grayscale when processed. The facial features detection is completed in still images. If a video is analysed the frames are analysed after one another. The scale of the face in the bounding box, the frame, the rotation and translation are all used to process the image.

## C.2 Gaze Tracking

The gaze tracking and the direction of gaze are estimated relatively to the persons head. The solution covers head pose and eye rotation. The gaze tracking is derived from the facial feature tracking and is based on landmark detection in the area of the eyes. The gaze tracking is completed in horizontal and vertical rotation. The inter-pupillary distance is used to determine the distance between the person and the camera. The inter-pupillary distance is a predetermined average distance. If the system requires accurate facial distances as output this is a very important measurement. To create a continuous output, the analysis has to be performed for each frame.