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SYSTEM FOR ANALYSIS OF ANIMAL EXCREMENT IMAGES**Technical Field**

5 The invention relates to a computer-based method for keeping animals, and more particularly to methods for maintaining and improving the health of animals. In particular, the method can be used for automatic detection of management errors and early detection of emerging diseases and production disorders.

10 Prior art

 When animals are kept together, especially in factory farming, outbreaks of diseases can occur repeatedly, which can lead to high losses in the animal population. Due to close proximity and sharing of common watering and feeding areas, diseases can spread rapidly and result in high economic losses due to death or slowed growth of the animals. To minimize risks and losses, many farmers also administer medications, including antibiotics, for purely prophylactic reasons. On the one hand, this is expensive and has the considerable disadvantage of promoting the emergence of multi-resistant pathogens, which can also be dangerous to humans. In addition, these preventive measures are undesirable to the consumer and reduce the quality and commercial value of the meat, eggs or milk from these preventively treated animals. Animal diseases are usually detected by personal inspection by the farmer or veterinarian once a sufficiently large number of animals are affected. However, since health inspections are only carried out on a random basis and sick animals are usually only noticed at an advanced stage of the disease, the outbreak of a disease is regularly detected too late, so that it is often already too late for medical countermeasures or, as a consequence, requires a massive use of expensive and/or for other reasons undesirable measures, for example the use of high doses of antibiotics. The closest prior art is disclosed in CN 208 080 199 U, a method for keeping animals.

30 Computer based systems and methods for monitoring the health status of groups of animals are now also known in the prior art. For example, U.S. patent application US 2010/0198023 A1 describes the use of a database as well as a plurality of data acquisition units, in particular sensors of various types, to monitor the health of animals in an animal

house. The sensors may include, for example, acoustic sensors, vitality meters, ammonia sensors, visual sensors, and odor sensors.

However, many of the computer based early detection systems in use today still have several technical drawbacks.

5 For one, some types of sensors used to automatically monitor the health of animals in animal housing facilities are very expensive to purchase and operate. For example, some sensors, such as sensors for specific gases or other vitality indicators, must be installed in appropriate locations by trained personnel and monitored regularly. For smallholder farms, but also for medium to large farms in developing and emerging
10 countries, the use of complex and expensive sensors is not an option due to the lack of money as well as trained personnel to install and maintain the sensors as well as to interpret the measured values. In addition, complex sensors are also prone to failure. When sensors are installed in animal houses, the sensors can easily become contaminated when they come into contact with, for example, excretions, saliva, bedding, feed, or
15 feathers of the animals and can then provide false readings - in the worst case unnoticed for long periods of time.

 Moreover, many of the existing computer based early warning systems have not been tested at all or have only been tested on a small number of animals and/or animal houses. It has been shown that even small changes in environmental parameters can
20 falsify the measurement or prediction results of some systems based solely on readings from temperature or humidity sensors. Other types of sensors are also often susceptible to interference or are not very predictive of animal health for other reasons. For example, room acoustics in an animal house depend on the size of the animal house and what the walls or other furnishings of the house are made of, factors that have nothing to do with
25 animal health. Humidity and temperature sensors can sometimes give widely varying results depending on how high off the ground and at what distance from a door or window they are placed.

 Overall, therefore, many computer-based methods for monitoring animal health in animal houses and similar facilities cannot be used in practice because they are not
30 sufficiently robust to variations in environmental parameters and because they are too expensive and technically demanding to commission and maintain.

Technical problem and fundamental solutions

Accordingly, the invention is based on the task of providing an alternative or improved method for keeping animals, as well as corresponding computer systems and storage media. Said method and/or computer systems or storage media can be used, in particular, for automatic detection of poor keeping conditions, for early detection of emerging diseases and production disturbances, for monitoring suitable measured values and measurement methods, and/or for manual or automatic execution of actions to improve animal health.

The tasks underlying the invention are each solved with the features of the independent patent claims. Embodiments of the invention are given in the dependent claims. The embodiments and examples given below can be freely combined with each other, provided they are not mutually exclusive.

In one aspect, the invention relates to a method of keeping animals according to claim 1. Other aspects include a system for keeping animals according to claim 20, a mobile robot according to claim 22, and a combination made up of a feed additive and the system according to claim 20, according to claim 23. In particular, the animals may be livestock, e.g., pigs, cattle, sheep, goats, rabbits, and poultry of all types, but in particular not excluding other types of animals, chickens, laying hens, and turkeys.

The method includes inputting at least one image into an analysis software. The at least one image is a digital image which depicts excretions from one or more of the animals. For example, inputting the image to the analysis software can include the analysis software receiving the image directly from an image capture unit, such as a camera, or the analysis software receiving the image over a network from a remote computer system or from an image capture unit coupled to that remote computer system. However, inputting the image may also include reading the at least one image from a storage medium. For example, the analysis software may be installed on a particular computer system and may read the at least one image from a storage medium of that same computer system.

The analysis software performs an analysis of the at least one image. Various analysis methods may be used here. Typically, an image analysis is first performed to extract individual features of the image ("feature analysis/feature extraction"). These features can include, for example, brightness and contrast values, color values (for example R, G, B values for RGB color images), objects detected in the image such as circles,

lines, polygons or structures (graininess, homogeneity) and other features. The extracted features are then evaluated to obtain one or more results of the analysis. For example, a training data set may include images of excretions of worms of a specific species and/or developmental stage, and by training machine learning software, the resulting analysis software may be made to automatically recognize objects of specific contour, color, texturing, and/or size as worms of a specific species in the course of image analysis.

In a further step, the analysis software outputs a recommended action, which is suited for maintaining or improving the current physiological state of the animals. The recommended action depends on a result of the analysis of the at least one image.

Additionally or alternatively, the analysis software outputs a predicted manifestation of a performance indicator of one or more of the animals. The performance indicator is a physiological parameter, a disease symptom, or a disease. The predicted manifestation depends on a result of the analysis of the at least one image.

This can be advantageous because images of excretions are readily available. Metadata such as currently administered substances (medicine, animal feed, additives) can also be easily entered via a GUI of the analysis software. Thus, according to embodiments of the invention, no special knowledge or additional equipment or sensors are required to easily, quickly and accurately check the health status of animals in a herd and quickly take appropriate action to protect or improve the health of the animals. A camera to capture the images is available virtually everywhere thanks to the ubiquitous proliferation of smartphones. Images of excretions are not dependent on irrelevant parameters such as the size of the pen or whether a window or door is open, for example, on which the temperature and humidity of the pen may depend. Image-based analysis also does not require the performance of difficult and hardly reproducible measurement procedures (measurement of internal body temperature), etc.

The excretions are in particular feces, preferably "fresh" feces, the excretion of which has occurred, for example, less than 12 hours, in particular less than six hours, preferably less than one hour before the time of the image recording.

According to embodiments of the invention, the excretions fill at least 40%, preferably at least 60%, of the area of the at least one image. For example, the analysis software may include a filter function that is adapted to first detect regions on the image that represent precipitation. Images with an area fraction of imaged excretions below a predetermined minimum value are discarded and not considered in the analysis.

Alternatively, if resolution permits, the analysis software may automatically consider only a sub-image of the received image for analysis, provided that this sub-image includes the required minimum percentage of imaging of excretions. According to some embodiments, the analysis software includes a filter function that discards images if they do not have a certain minimum resolution and/or contrast. Preferably, the analysis software may issue a warning message alerting the user of the analysis software that the at least one input image does not meet the required quality criteria to allow the user to capture one or more new images.

According to embodiments of the invention, capturing the at least one image of the excretions includes irradiating the excretions with light from a light source while capturing the at least one image. The irradiation may be very brief (flash light, exposure time typically less than one second) or may last for several seconds.

According to embodiments of the invention, the method comprises sending a control command to an illumination unit. For example, the control command may be sent by the analysis software or a software (camera software) associated with the image capture unit, e.g., a smartphone. The control command causes the illumination unit to illuminate the excretions with light of one or more defined wavelength ranges during the capture of the at least one image of the excretions. One or more images of the excretions are then captured during illumination of the excretions with light of the one or more wavelength ranges, respectively. In particular, the illumination unit may sequentially illuminate the precipitates with the light of a plurality of defined wavelength regions, for example for a few seconds. During illumination with each of the defined wavelength ranges, the image capture unit captures one or more wavelength range-specific digital images of the precipitates. Optionally, a color reference object with one or more color dots may also be illuminated and captured. The analysis software is adapted to carry out the analysis in a wavelength range-specific manner selectively for the one or more images captured with light of the respective wavelength range.

According to preferred embodiments, the analysis software (or the part of the analysis software configured as a client application) includes an illumination function, which may be configured, for example, as an illumination module of the analysis software. The illumination function is operatively coupled to and can control the light source. For example, the illumination function may control the illumination duration and/or intensity and/or wavelength range of the light emitted by the light source. Preferably, the

illumination function includes a program for illuminating the precipitates with at least two or more light pulses of predefined, different wavelengths or wavelength ranges. Preferably, the illumination function is also operatively coupled to an image capture unit and is capable of synchronizing the capture of the at least one image with the illumination function. In particular, the synchronization may be such that at least one image is captured per time interval at which the precipitates are illuminated with one of the predefined different wavelengths or wavelength ranges of the light source and entered into the analysis software and/or stored in a database for later use. This can be advantageous because the excretions are now illuminated with the light of different wavelength ranges and important optical and, in particular, color properties of the excretions can thus be better characterized. For example, excretions with a high proportion of non-oxidized blood (excretions with a bright red color) absorb blue and green light particularly well, while red light is reflected more strongly. By sequentially irradiating the excretions with light of different wavelength ranges, e.g. blue: 450-482 nm, green: 497-530 nm, red: 620-780 nm, and capturing one or more images per wavelength range used of the same excretions, very meaningful information about the spectral properties of the excretions can be obtained even under poor and difficult to exactly reproduce measurement conditions (which are typical for the use of smartphone cameras at different locations in the animal house, possibly also by different workers).

Preferably, the light source is a light source that is incorporated into the image capture unit or the device that includes the image capture unit, such as a smartphone. For example, the light source may be a flash light of a camera. In one embodiment, the light source is the display of a smartphone. This embodiment may be advantageous because no special aparative equipment (other than the smartphone) is required to illuminate the precipitates with light of two or more different wavelength ranges and capture corresponding images. It is true that most smartphone displays are not capable of selectively emitting light only in a very narrow and highly precise wavelength range as, for example, laser devices can. However, it is possible to achieve a sequence of defined illumination processes of different wavelengths by e.g. displaying first the rgb color value 255,0,0 for "red", then the rgb color value 0,255,0 for "green" and then the rgb color value 0,0,255 for "blue" on a LED display. Depending on the embodiment, other wavelength ranges or color values can also be used in the color space of the display. Preferably, the analysis software is machine learning software that has been trained on a data set of

training images of excretions of the animals, wherein at least some of the training images have been selectively illuminated with only light of one wavelength or with light of a wavelength range that can be generated by the light source. Preferably, the training data set thereby covers all wavelength ranges sequentially used by the illumination source or
5 by the illumination function, respectively, i.e., the training data set includes multiple images of excretions that were illuminated at light of each of these defined wavelengths or wavelength ranges. Thus, the illumination function and the analysis function of the analysis software form a functional unit. This can be advantageous because with the simplest of means (smartphone with camera and a program implementing the
10 illumination function), a large amount of spectral information of the excretions of the animals can be captured, which can also be used by the trained machine learning algorithm to enable accurate analysis and prediction or output of the analysis results.

However, according to alternative embodiments, the lighting unit may be specialized lighting devices that are not part of currently commercially available
15 smartphones. For example, the illumination unit may be a laser light source and/or a light source in a wavelength range that is not visible (to humans), e.g., in the infrared range (e.g., 850-950 nm) or UV light range (280-380 nm).

The physiological parameter may be, for example, a body temperature, a measured metabolite concentration, body weight, feed consumption, water consumption per
20 animal per unit of time or per group of animals or house per unit of time, etc. For example, in some embodiments, the water consumption and/or feed consumption may be manually entered via a GUI of the analysis software and/or may be automatically obtained by the analysis software from corresponding sensors or counters of a watering system or feeding system of the animals.

In this respect, in a further aspect, the method for keeping animals also provides a method for computer-based monitoring of the health of the kept animals and/or a method for early detection of a predicted drop in performance, such as due to a disease. In a further aspect, the method constitutes a method for computer-assisted detection of poor or improvable keeping conditions, in particular of deficiencies or malnutrition, that
30 may occur in animal keeping.

According to embodiments, the method comprises capturing the at least one image by an image capture unit, in particular a camera. The camera may be, for example, a portable camera, in particular a smartphone camera or a camera. In particular, the camera

may be the camera of a smartphone of a person working in the animal house. This can be advantageous, since even in developing and emerging countries the vast majority of people own smartphones with integrated cameras and are familiar with their operation. Thus, it is not necessary to install special sensors in the stables or enclosures, to maintain
5 them regularly, and to train the personnel.

Alternatively, however, the image capture unit may be a camera that is permanently installed in the animal house, enclosure, or other space in which the animals are kept. According to another alternative embodiment, the image capture unit is a camera that is permanently installed on a mobile robot or a conveyor belt. The robot or
10 conveyor is adapted and appropriately positioned to move in a terrain on which the animals are kept. For example, the camera may be mounted at a suitable height and angle that ensures that images are captured of the ground of the terrain on which droppings are regularly found. Combinations of image capture units of different types can also be used. The use of robots and/or conveyor belts with a camera can be advantageous, as this
15 can eliminate the need to manually take the photos and keeps the shooting conditions particularly constant. These embodiments are particularly useful when the degree of automation of the mast operation is high, and have the advantage that, for example, the shooting angle remains constant. The fact that the camera is mounted on a mobile unit ensures that recordings from different areas of an animal house or terrain used for animal
20 keeping can be analyzed, so that the data basis can be enlarged and the quality of the analysis results can be increased.

According to embodiments of the invention, capturing the at least one image includes positioning a color reference object in spatial proximity to the excretions whose image is being captured. The color reference object has one or more different colors in
25 defined regions of the color reference object. The analysis software is adapted to use the colors of the color reference object in the analysis of the at least one image to normalize the colors of the precipitates imaged in the at least one image. In addition to the precipitates, the at least one image also depicts the color reference object.

For example, the color reference object may be a paper or plastic strip on which
30 one or preferably more color dots are applied at defined locations known to the analysis software, the color dots having a defined color and/or brightness value. A worker who takes pictures of the animals' excrement with his smartphone camera during his daily inspection walk through the animal house holds the color reference object over or next

to the excrement during the recording, so that the recorded picture shows both the excrement and the color reference object. Preferably, the color reference object and the analysis software are provided by the same vendor, and the analysis software is adapted to normalize, based on the colors and/or contrast values of the color reference object, the colors, brightness and/or contrast values of the at least one received image.

This may be advantageous because the normalization of the color values and/or brightness values of the received images by the analysis software based on the color reference object ensures that the analysis software will provide the same results even though the lighting conditions may be different in different animal houses or different areas of the same animal house or at different times of the day. It is also possible that different types of cell phones or smartphone cameras are used by different workers and that this will cause some variation in the brightness and/or color space of the images captured by these cameras. Thus, normalizing the colors and brightness values of the images based on the color reference object may be advantageous, as this may provide robustness to the analysis results with respect to different camera types and/or different lighting conditions when the images are captured. The use of a color reference object may be advantageous, since this very simple measure may ensure a high reproducibility of the captured images and a high quality of the analysis results.

According to embodiments of the invention, the action output by the analysis software is an action to be performed at a specific action point in time. The action point in time may be a current point in time or a future point in time starting from the analysis point in time. For example, the analysis software may output that the feed must be changed immediately to prevent the animals from becoming deficient in certain minerals. It is also possible that the output of the analysis software includes that a certain action such as change of feed composition or administration of a certain drug has to be done immediately without delay or is only required at a certain time in the future, for example after two days starting from the time of analysis. Whether the time of action is in the present or future depends on what the action is, and how clearly, given the excretions depicted in the received image, the analysis software deems a particular action necessary. This in turn may depend on the rules or training data set that were used to generate the analysis software. For example, it may be advantageous not to immediately perform an action that is particularly expensive or associated with disadvantages/side effects (for example, administration of an antibiotic) when symptoms are unclear, but to output that

administration is recommended in 2-3 days. This gives the animal owner the opportunity to order the appropriate medication in time or also leaves open the possibility of foregoing medication administration if the analysis software comes to the conclusion, based on images of excretions on the following day, that antibiotic treatment can be omitted because the disease had affected only a few animals and is already in decline on its own.

Additionally or alternatively, the predicted manifestation of the performance indicator may be a manifestation that is predicted to occur at a manifestation point in time. The manifestation point in time is a future time starting from the time of the analysis.

Preferably, the analysis software is adapted to calculate the prediction of the manifestation of the performance indicator at the manifestation point in time and the recommended action at the action point in time such that the action point in time is a sufficient amount of time before the manifestation point in time to allow the execution of the recommended action at the action point in time to influence the manifestation of the performance indicator at the manifestation point in time in a specific, desired manner (positive or negative). For example, the analysis software can be designed to detect and predict the outbreak of certain diseases, such as population-wide coccidiosis or clostridial infestation, 2-3 days before the actual population-wide outbreak, based on characteristics specifically attributable to these diseases, such as color characteristics of the blood visible in the images of the excretions of some animals that already show slight disease-related changes. This period of time is usually sufficient to enable the operator of the animal houses to initiate countermeasures in time. Countermeasures may include, for example, administering medication against coccidiosis and/or clostridia, identifying and separating already infested animals, administering a particularly high-quality or digestible feed, increasing the temperature or humidity, and the like.

According to embodiments of the invention, the recommended action includes one or more actions. These actions may include, for example: a provision of a particular animal feed or drinking water; an administration to the animals of one or more medicinal or non-medicinal substances in a physiologically effective form, in particular minerals, vitamins, drugs (e.g. via feed, drinking water, air, etc.); a termination of an ongoing administration of one or more medicinal or non-medicinal substances in physiologically active form to

the animals; a change in the physical parameters of an animal house or premises in which the animals are kept, in particular humidity, and temperature.

According to embodiments of the invention, an output of the predicted manifestation of the performance indicator and/or the output of the recommended action is provided to a user via a user interface of the analysis software. In particular, this user interface may be a graphical user interface, a so-called GUI.

Additionally or alternatively, the output of the recommended action is provided to an electronic or mechanical system operatively coupled to an animal stable or an area in which the animals are kept. The electronic or mechanical system is adapted to carry out the action in response to receiving the outputted action.

For example, this electronic or mechanical system may be the heating or ventilation system of the animal house or a feeder or waterer. Preferably, the appropriate action can thus be taken automatically to adjust physical parameters of the animal house to maintain and/or enhance animal performance and health. For example, the drinking water supply or feed addition can be increased to meet increased needs, or the feed addition can be reduced if the animals are suffering from acute appetite. More minerals or vitamins may also be automatically added to the feed, for example as a prophylactic or curative measure.

According to embodiments of the invention, the disease is coccidiosis, a clostridial infection, salmonellosis, cryptosporidiosis, a disease caused by gastrointestinal parasites such as, in particular, gastric worms or intestinal worms or unicellular pathogens, coli sepsis, lawsoniosis, or swine dysentery. However, the disease may also be any other disease that manifests itself in a characteristically altered appearance of the animal's excretions. If necessary, for each of these other diseases, a training data set in the form of training images of the excretions of healthy animals as well as animals suffering from this disease must be created in order to train a machine learning algorithm on this training data set in order to generate the analysis software, or corresponding rules must be manually defined for the respective disease, according to which the analysis software performs the analysis.

According to embodiments of the invention, the animals are poultry, cattle, sheep, or pigs.

According to embodiments of the invention, the analysis software is software based on predefined rules. This can be advantageous because rules can be created and

interpreted by humans. It is thus possible to incorporate human expert knowledge into the software. However, rule-based systems also have the disadvantage that the rules must be explicitly formulated. Thus, predictive parameters that are not known to the programmer cannot be incorporated into the software.

5 According to embodiments, the analysis software is trained machine learning software. This can be advantageous, as it is possible to obtain analysis software by training the software on a sufficiently large data set, which can also recognize predictive features that are not known to humans, e.g., combinations of certain features of the images of the excretions, such as granularity, moisture, color of the imaged excretions, but also
10 combinations of features of these images with measured values and/or metadata regarding administered substances, and take them into account in future analyses. It is true that the features and feature combinations learned by the machine learning software during the training process are usually not explicitly stored in a way that can be interpreted by a human. To this end, machine learning systems can use a large number of
15 features and feature combinations to evaluate them in terms of their predictive power, and can use combinations with high predictive power, often unknown to humans, for future analysis and prediction.

 According to embodiments of the invention, the method further comprises providing a training data set, which contains a plurality of training images of excretions
20 from animals of the same animal species as the animals that are to be kept. The training images are annotated (stored linked) with metadata. The metadata contains at least one performance indicator of the animal or animals whose excretions are depicted in the training images. The metadata also includes the composition of the feed or water given to those animals at the time the training images were captured. The method includes
25 generating the analysis software by training a machine learning software based on the training images.

 For example, the predicted manifestation of the performance indicator may include a predicted severity and/or duration of the manifestation of the performance indicator, particularly the severity and/or duration of a disease symptom or disease. The
30 recommended action may contain, for example, a recommendation on the type and amount of medication, feed, feed additive, and/or drinking water additive to be administered to the animals to maintain or promote the health of the animals. The

predicted manifestation of the performance indicator may also include an indication of possible causes of a predicted decline in performance.

According to embodiments, the at least one image comprises a plurality of images. This may be advantageous as it increases the size of the data base, thereby increasing the quality of the analysis. By taking a plurality of images at a certain point in time, for example during a routine daily inspection walk through the animal house by an employee, it is possible to evaluate images of excretions from a plurality of animals and preferably also from different areas of the animal house or the grounds on which the animals are kept. This can reduce the influence of so-called "outliers". In addition, the situation can arise that initially only a few animals of a livestock are affected by a contagious disease and thus only the excretions of these few animals show changes. By capturing multiple images of excretions from multiple different animals at a given time, it is also more likely that the images analyzed will include excretions from these few affected animals, so that countermeasures can be taken quickly. In addition, different animals may react in different ways or to different degrees to a particular pathogen or other environmental parameter. By capturing multiple images, the analysis software can gain a better overview of the prevailing variance of different characteristics of the excretions, thereby improving the quality of the analysis.

According to embodiments, the input of the at least one image and the analysis of the input at least one image are performed regularly with a frequency of at least once per day. The respective inputted images are digital images, each of which is currently captured and represents current excretions from one or more of the animals. In each case, the analysis is selectively performed on those of the received images that were captured within a predefined time period prior to the time of the analysis. For example, the analysis may relate not only to the currently captured images, but to all images captured within a predefined time period, for example 5 days or 7 days or ten days calculated from the current day on which the further images are captured and analyzed by the analysis software. The analysis of all images taken within a shifting and relatively short time window of a few days to weeks can be advantageous, as this increases the database and improves the quality of the analysis results. Analysis of images taken over several days makes it easier to identify trends, for example, improved or worsened feed conversion, pathologically altered excretions, prevalence or increase in diarrheal disease, etc. It has been observed that exclusion of images taken more than a certain period of time ago,

e.g., 5 days, 7 days, or 10 days, can also improve analytical results, as images of this age or even older are generally no longer predictive of current or future performance indicators.

5 Optionally, the analysis software (or a portion thereof formed as a client application) may be adapted to store one or more reference images of excretions from animals of a particular animal house associated with one or more metadata. The analysis software or the client application is further adapted to allow a user of the analysis application to cause the analysis software to selectively output these reference images using a selection filter on one or more of these metadata, e.g., via a display of a
10 smartphone. The metadata may be, for example, the date the image was taken, an identifier of the animal house or premises where an image was taken, geospatial data from the location where the image was taken, time of year, species of animal, breed of animal, type, origin, and/or amount of one or more currently administered substances or mixtures of substances (feed, feed additives, medications). The storage of reference
15 images and the possibility of metadata-driven output of the reference images can be advantageous, as it gives the user an additional possibility to check the outputs of the analysis software for plausibility. If, for example, the analysis software does not detect any disease even though the currently photographed excretions look significantly different from the excretions photographed a few days ago at the same location, and even
20 though nothing has been changed in the feeding parameters, this is an indication that, despite the absence of a corresponding warning message, increased monitoring of the animals may be useful because, for example, a disease may have broken out that is not covered by the analysis software, e.g., because the analysis software has only been trained for salmonella, coccidiosis and clostridia, but currently a worm disease causes a
25 change in the color of the excretions.

For example, as shown above, one or more workers who perform an inspection walk through an animal house or enclosure one or more times per day may also take multiple images of the excretions of multiple animals at different locations in the animal house or enclosure using an ordinary smartphone camera on this occasion. The usual
30 workflow, for example, administering feed, changing bedding, checking the watering system, etc., is not significantly delayed by taking the images.

According to embodiments of the invention, the method comprises providing a feed or drinking water to the animals of the animal house, wherein the feed or drinking

water is admixed with an indicator substance that causes a coloration in the excretions of the animals that depends on physiological state in the metabolism of the animals.

For example, the indicator substance may be a pH indicator. This can be advantageous because fecal pH can be used as an integrated indicator of a variety of metabolic processes in the intestinal tract of animals. It allows conclusions to be drawn about the metabolic performance of various groups of microorganisms in the intestine, since the fecal pH depends on the composition of the intestinal flora and thus indirectly on the feed administered, which is metabolized by the microorganisms. Carbohydrate compounds, especially dietary fiber, are converted by some bacteria to short-chain fatty acids, thus causing acidification of the intestinal environment and excretions. Protein-rich feed, on the other hand, stimulates the proteolytically active intestinal bacteria, which form ammonia and other metabolic products with an alkalizing effect from it. The sum of these processes results in pH values between 6.0 and 7.0 in intestine-healthy adult pigs, for example. Unbalanced diets, diseases or other environmental factors can lead to a change in the composition or functioning of the intestinal flora and thus to a shift in the pH value of the excretions. Disorders of protein and/or fat digestion (exocrine pancreatic insufficiency, bile acid secretion disorder, etc.) but also inflammations with loss of plasma proteins can cause an increased transfer of these substances into the colon and an alkalization of the excretions. On the other hand, a diet rich in fiber, but also a carbohydrate intolerance, makes itself felt with an acidification of the stool. The pH indicator can be, for example, betaine or another betacyan with a pH-indicative effect, or an anthocyanin. The dye betaine is found mainly in red beet (*Beta vulgaris*), but also in the flowers and fruits of other plants. Betaine belongs to the group of betalains and their subgroup of betacyans. The glycoside betanin is a readily water-soluble dye whose color in aqueous solution depends on the pH: In the strongly acidic pH up to 2, the solution is violet; at pH 4, there is a color change to red. In the strongly basic range, the color changes to yellowish-brown under hydrolysis of the glycosidic bond. This produces the aglycone betanidin and glucose. Other pH indicators can also be used as feed additives or drinking water additives. Anthocyanins, e.g., cyanidin-3-triglucoside, give red cabbage a pH-dependent red to blue color. A variety of pH indicators are known from the prior art, such as litmus, bromothymol blue, phenolphthalein or combinations of these substances. Preferably, pH indicators are used which are inexpensive and chemically stable, which are

not completely metabolized even upon passage through the gastrointestinal tract, and which are physiologically tolerable.

The administration of feed or water with the indicator substance has the advantage that the recordings of the excretions may contain additional information on relevant physiological parameters, such as the pH of the excretions, which allow a more accurate prediction of the manifestation of a particular performance indicator. The pH of the excretions is not in itself detectable from the digital images. Thus, by administering the indicator substance and using analysis software that has been adapted to administer the indicator substance (e.g., by means of training on a training data set, which contains images of excretions even from animals to which the indicator substance has been administered), additional important information about the health status of the animals can be obtained without complicating the data collection process for the ordinary worker.

According to an alternative embodiment, the indicator substance is not added to the feed or drinking water, but is applied to the excretions shortly before the at least one image of the excretions is taken. This may have the advantage that a smaller amount of the indicator substance is consumed and physiologically harmful substances that are not suitable as nutritional supplements can also be used. However, it does make the step of acquiring the image somewhat more time consuming.

In an analogous manner, the proportion of undigested fats, fatty acids, certain carbohydrates such as starch and/or the proportion of certain amino acids, peptides and proteins in the excretions can also provide information about the health status of the animals and, in particular, about the presence of specific digestive problems. Thus, by adding appropriate indicator substances directed at the aforementioned substances, which cause a color change in the excretions depending on the content of fats, fatty acids, certain carbohydrates, amino acids, peptides or proteins, as an alternative or in addition to the administration of the pH indicator, a variety of additional information can be obtained. Preferably, in this case, the analysis software includes a GUI which allows the user to enter the one or more indicator substances administered as metadata into the analysis software so that this information is taken into account when performing the analysis and is included in the analysis result.

According to a further embodiment, the indicator substance is a fluorescent dye or a substance coupled to a fluorescent dye. Preferably, the chemical resistance and/or the excretion rate of the indicator substance depends on physiological parameters of the

intestinal tract of the animals, e.g., the presence of inflammation or parasites in the gastrointestinal tract, the pH value, the intestinal flora, and other factors. Preferably, the image capture unit used to capture the at least one image is coupled to a light source that emits light at a wavelength that can excite the fluorescent dye to fluoresce and emit
5 fluorescent light. Optionally, the at least one image can be captured using a color reference object that includes a color dot having a defined amount of that fluorescent dye.

For example, unlike many other organic acids, only 30% of gluconic acid is absorbed in the small intestine of most mammals. Most of this substance is metabolized by various
10 intestinal bacteria to acetic and lactic acids, which in turn are further metabolized to health-promoting short-chain fatty acids such as butyric acid and propionic acid. The concentration of several other organic acids and their metabolism also depend on the physiological conditions in the gastrointestinal tract, so the concentration of these metabolites in the excretions can provide information about possible diseases. However,
15 the detection and quantification of individual chemical substances is too laborious in many cases. According to embodiments, the animals are administered an indicator substance that is coupled to a fluorescent dye or that itself has fluorescent properties and whose concentration in the excretions of the animals depends on the physiological conditions in the gastrointestinal tract. For example, German patent DE69726135T2
20 discloses fluorescent complexes of tri- and tetracyclopolyazamacrocyclic compounds that are suitable for biological applications because they are stable in aqueous media and non-toxic. In particular, chelating agents based on tetraazamacrocyclic backbones are suitable for generating aqueous stable lanthanide chelates. Aminocarboxylate and aminophosphonate chelating agents derived from 1,4,7,10-tetraazacyclododecane form
25 highly stable lanthanide chelates that have proven particularly suitable as feed or watering additives, since their concentration in the excretions allows at least rough quantification and thus conclusions about animal health in the course of analyzing images of the excretions excited to fluorescence with a suitable light source. In contrast to conventional fluorescence immunoassay methods, the procedure is very easy to apply.
30 Although a rough quantification based on the fluorescence signal is also performed here, the analysis is not based on complicated immunological assays but on the administration of a fluorescent indicator substance with the feed or drinking water and an automated evaluation of corresponding fluorescence images of the excretions.

Suitable lanthanides include, for example, terbium (Tb) and europium (Eu) which use coupled to a small molecule without necessarily being an antibody. This molecule is, for example, bifunctional chelating agents as described in patent DE69726135T2, and which may be covalently linked to biologically active substances, in particular substances that are typically metabolized in the gastrointestinal tract such as dextran, and pharmaceutically acceptable salts thereof. "Pharmaceutically-acceptable salts" as used herein means any salt or mixtures of salts which is/are sufficiently non-toxic to be applicable for diagnosis in animals, preferably mammals. The biologically active substances may be, in particular, organic substances such as. Acetic acid, succinic acid, citric acid, lactic acid, maleic acid, fumaric acid, palmitic acid, cholic acid, palmonic acid, mucic acid, glutamic acid, gluconic acid, d-camphoric acid, glutaric acid, glycolic acid, phthalic acid, tartaric acid, formic acid, lauric acid, steric acid, salicylic acid, methanesulfonic acid, benzenesulfonic acid, sorbic acid, picric acid, benzoic acid, cinnamic acids, and other suitable acids.

To reduce costs, the fluorescent indicator substances may also be administered to only a few selected animals for a short period of time, for example, to get an even more accurate picture of a health problem that may be present. For example, the indicator substance can be administered in a range of 0.01 - 1 mmol/kg body weight of the animal, but the recommended dose will depend on the particular substance and species. In general, enough of the indicator substance should be administered so that a clearly measurable amount of the indicator substance is still present in the excretions of a healthy animal so that upward or downward deviations in concentration, which may be indicative of a health problem, can be clearly measured and detected by the imaging unit.

This can be advantageous because the intensity of the fluorescent signal from the excretions can provide information about the extent to which the indicator substance was chemically degraded or absorbed during intestinal passage. Preferably, the amount of fluorescent dye per area in the color dot of the color reference object corresponds to that amount of fluorescent dye that would be expected in an identically sized area of the animal excretions in healthy animals. Variations in the intensity of the fluorescence signal provide information about various physiological states of the gastrointestinal tract of the animals.

Depending on the application, the indicator substance may be added in response to a predicted manifestation of a performance indicator, such as when the analysis

software already predicts the occurrence of diseases of the gastrointestinal tract for the next 2-3 days and the addition of the indicator substance is intended to ensure that additional information regarding the digestive tract is obtained. However, it is also possible to administer the indicator substance prophylactically. For example, the analysis
5 software may be adapted to predict the presence of the disease based on recordings of excretions from animals that have ingested the indicator substance in food or drinking water.

According to embodiments, the analysis software has been trained on a training data set comprising images obtained from excretions of animals (with different
10 performance parameters, healthy and sick animals) that have ingested the indicator substance with food or drinking water, or to which the indicator substance has been added directly after the excretions have left the animals' bodies. The latter can be done, for example, by nebulization or instillation of the indicator substance onto the excretions. The analysis software is designed to automatically detect the current or future presence
15 of a disease and/or other performance indicators in the animals based on visual characteristics of the excretions, in particular their color, where the visual characteristics of the excretions depend both on the presence of the disease and/or the performance condition of the animal and on the administration and concentration of the indicator substance. In particular, the animals kept are animals kept together, e.g., in the same
20 animal house or the same premises.

According to embodiments of the invention, prior to taking the at least one image, the animals are provided or administered with a feed or drinking water to which an indicator substance has been added, wherein the indicator substance is a substance that causes a coloration in the excretions of the animals that depends on the physiological
25 condition of the animals, in particular the infestation of the animals with pathogens. In particular, the indicator substance may be a pH indicator.

According to embodiments, the analysis software is adapted to receive digital images of all or more of the animals at regular time intervals in addition to digital images of excretions. The images are time stamped and are preferably received at a frequency of
30 at least once per 10 seconds, preferably at least once per 5 seconds, further preferably at least once per second. Preferably, these images are received from one or more stationary cameras of the animal house or premises where the animals are kept. The analysis software performs image analysis of the images with the time stamps to recognize

individual animals as objects and to calculate a movement profile for the animals over time. The mobility of the herd is an indication of the health status of the animals. A herd that is quiet but mobile is healthy. A higher movement frequency can indicate certain diseases or too low temperatures, a decreased movement frequency can also indicate diseases, e.g. viral infections, or too high animal house temperatures. The movement profiles may be used in a complementary manner to refine the analysis based essentially on the analysis of the excretory images.

According to embodiments, the analysis software has access to a database containing data on stocks of a keeper of the animals of various substances or mixtures of substances, in particular feed compositions, feed additives, drinking water additives, vitamins, minerals, and veterinary preparations. The database may contain other data, e.g., actual measured performance indicators of animals of the animal house or animal enclosure, which are also associated with images of their excretions taken in temporal proximity to the measurement of that performance indicator. The measured performance indicators can be, for example, images of the gastrointestinal tract of slaughtered animals, of which images of the excretions of these same animals were taken a few hours or days before their slaughter, which are preferably also stored in the database and can be used to generate or improve the analysis software by training or retraining a machine learning algorithm.

The analysis software automatically checks whether the supplies are exhausted after the amount and type of substance or substance mixture taken from the supplies according to the recommended action with respect to that substance or substance mixture. The analysis software then sends an order message to an electronic ordering system of a supplier of the withdrawn substance or substance mixture over a network.

For example, the database may be a commodity management software database to which automatic ordering software is attached. When the operator of the animal house removes a particular substance, for example, a bag of feed, a package of a feed additive, or a veterinary preparation from the inventory, the removal is automatically or manually entered into the commodity management software, ensuring that the inventory held in stock is always currently accounted for. In some embodiments, the commodity management software is operatively coupled to consumption sensors of machines and equipment that directly or indirectly indicate the consumption of a substance. For

example, the consumption sensors may be consumption sensors of feeding machines or water meters of watering systems.

Automatic replenishment can thus simplify animal keeping and speed up associated processes, as the analysis software in conjunction with the commodity management software automatically ensures that the inventory of required substances is automatically maintained or replenished.

According to embodiments, the method comprises a manual or automated input of at least one measured value into the analysis software. The at least one measured value may comprise, for example, one of the following measured values or combination of two or more of these measured values: Temperature of the milk delivered by the animals; Electrical conductivity of the milk delivered by the animals; Temperature of the animal house; Ammonia content in the; Humidity content of the air; preferably the distance of the sensors from the ground is less than 20cm, preferably less than 10cm; Amount of feed delivered per animal or per animal house per time unit in the last measured time unit; Amount of drinking water delivered per animal or per animal house per time unit in the last measured time unit. The analysis software then performs an analysis of the at least one measured value in addition to the analysis of the at least one image. The recommended action and/or the predicted manifestation of the performance indicator depends on the result of the analysis of the at least one image and on a result of the analysis of the at least one measured value. Said measured value parameters have the advantage that they are collected and gathered on a daily basis anyway in many animal houses by sensors for the animal house management software in order to control the ventilation and other technical equipment of the animal house and are thus already available, comparatively easy to collect and robust against environmental influences.

Preferably, all said parameters are measured in temporal proximity to the time of recording of the at least one digital image, for example within the same hour or within a period of 6 hours or within the same day. Said measured values, if the facility of the animal house or premises where the animals are kept already has appropriate sensors, can be taken into account in a complementary way in the prediction of the performance indicator and/or in the calculation of the recommended action by the analysis software. However, usually the images of the excretions alone are sufficient to obtain an accurate analysis result, so that the method is particularly suitable for keeping animals under technically simple conditions, i.e. without the use of additional sensors or without taking into account

the corresponding additional measured values. Preferably, the analysis software is a machine-learning software, during the training of which only some of the training images, but by no means all, were annotated with supplementary measured values such as, for example, milk temperature, floor temperature, etc. A sufficiently large part of the training data set comprises digital images of excretions from animals of which a current or future performance indicator or a current or future recommended action was known and stored linked to the respective images, but with which no measured values were stored linked. This can ensure that even in the absence of said measurement values as supplemental metadata, accurate analysis and output of analysis results can be performed by the analysis software.

Optionally, further data may be received, for example data entered by the user via a GUI of the analysis software, e.g. type and strain of animals, age of animals, sex of animals, composition of feed (possibly coded in the form of a feed type ID), etc. These other data also enter into the prediction. Thus, the prediction is then made as a function of the received images, of the further data ("metadata") such as, in particular, feed, feed additives, medications, etc., and of the measured values, if these have been received.

According to embodiments, the analysis software is implemented as a software application instantiated on a mobile computer system, in particular a smartphone. The analysis software is configured to receive the at least one image of the excretions from a camera of the mobile computer system, and, optionally, to receive metadata (such as currently administered substances such as feed, feed additives, and medications) and/or measurement data. The analysis software is adapted to carry out the analysis of the at least one image and output the recommended action and/or predicted manifestation of the performance indicator. For example, the analysis software may have a GUI that is displayed to the user of the mobile computing system via a display of that computing system and that allows the user to enter the metadata and/or the measurement values into the analysis software via the GUI. Alternatively, the analysis software may have a local interface to one or more sensors, e.g., thermometers, e.g., a Bluetooth interface or be connected to the sensors by means of a network, such as the Internet, such that the analysis software may receive measurement values from these sensors, according to some embodiments. This embodiment may be advantageous because both the acquisition and the analysis of the images may be performed using local means, all of which are available on the user's smartphone. For example, the analysis software may be

installed on the smartphone in the form of an app. The user is thus independent of other remote computer systems, which can be particularly advantageous in areas or buildings with no or unstable cellular connectivity and with no WLAN connection.

5 According to an alternative embodiment, the analysis software is designed as a distributed client-server software application. The client software is instantiated on a mobile computer system, in particular a smartphone, and is configured to receive the at least one image of the excretions from a camera of the mobile computer system and to send it to a server application instantiated on a server computer system. The server application is adapted to receive the at least one image from the client application, 10 perform analysis of the at least one image to calculate the recommended action and/or the predicted manifestation of the performance indicator, and send the recommended action and/or the predicted manifestation to the client application over the network. The client application is adapted to output the recommended action and/or the predicted manifestation to the user of the mobile computing system.

15 According to further embodiments, the analysis software is configured as a distributed client-server software application. Thus, the analysis software comprises a server application and a client application that are interoperable with each other over a network. The client application may be installed and/or instantiated on one or more client computers, the client computers each preferably being mobile computers, e.g., 20 smartphones or tablet computers. The server application may be connected to a plurality of client applications via a network. Here, each of the client applications is operatively coupled to an image capture unit, e.g., the camera of the smartphone on which the client application is respectively installed. Each of the image capture units may be located, at least at the time of image capture, within one of a plurality of different animal houses or 25 premises on which animals are kept. The server application is adapted to carry out the following procedure: Receiving at least one digital image by the server application from each of the client applications over the network. The at least one received image shows excretions from one or more of the animals of an animal house or premises where the animals are kept.

30 The server application is adapted to carry out an analysis of the at least one image based on the received at least one image and to send the result of the analysis, i.e., a recommended action and/or a predicted manifestation of a performance indicator, to the client application. The sending may be done over the network. For example, the result of

the analysis may be transmitted to the client application from which the at least one image was received, and the client application may be adapted to display the result received from the server application to the user of the corresponding client computer via a display. Additionally or alternatively, the output may be provided to a mechanical or electronic system operatively connected to an animal house to cause it to change an environmental or feeding parameter. This system may be, for example, a heating system, an air conditioning system, a watering system, a feeder of an animal house, or the like. Optionally, the client application may also be configured to receive measurement data from sensors and/or to receive metadata that a user manually enters via a GUI of the client application, and to forward the measurement data and/or metadata to the server application. The forwarded measurement data and/or metadata then provides an additional basis for analysis by the server application.

This can be advantageous because the server-side implementation of the analysis functionality can access and centrally store and evaluate the image data, and optionally also measurement data and metadata including real observed performance indicators, from a plurality of client applications and thus typically from a plurality of different animal housing facilities or animal populations. This allows continuous improvement of the analysis functionality through repeated training on a constantly growing data set. It allows to automatically detect incorrect predictions and recommendations based on the centrally collected data and to improve the algorithm, either by explicitly changing explicit rules in the case of rule-based analysis programs or by repeatedly training a machine learning program on a continuously growing training data set. Furthermore, it is possible to provide a lean client application, i.e., one that requires little memory and computing power. Its function is preferably limited to forwarding the images captured by the smartphone camera of the client computer to the server application, optionally providing a GUI that allows the user to enter metadata such as the feed currently being fed, and receiving the analysis results from the server application, with the analysis results preferably being displayed by the client application via a GUI to the user of the client computer.

According to embodiments, the analysis software (or, in the case of a client-server architecture, in particular the server application) is configured to receive at least one manifestation of a performance indicator of the animals of the animal house and optionally further animal houses measured or entered by a user via a GUI. For example,

the manifestation may be entered by the respective users of one or more client applications, each of which is responsible for different animal stables or animal herds, via the GUI of the respective client application and transmitted to the server application. In addition or alternatively, the manifestation may also be entered into the respective
5 feedback application via a GUI of one or more feedback applications and transmitted from the feedback application to the server application via the network. Each of the feedback applications is assigned to a slaughterhouse and is used, for example, to capture and forward images of the slaughtered animals. In particular, the manifestation of the performance indicator may be images of the gastrointestinal tract after slaughter of the
10 animals. Preferably, the manifestation of the performance indicator relates to a point in time in temporal proximity to the point in time of acquisition of the at least one digital image. For example, the performance indicator was measured on the day of slaughter, e.g. in the form of images of the gastrointestinal tract of the slaughtered animals, and the images of the excretions were taken on the same day or day before slaughter. So temporal
15 proximity here means preferably within 48 hours, preferably within 24 hours. These images may be appropriately annotated by a veterinarian, e.g., "small intestine of a broiler chicken with acute coccidiosis," "healthy small intestine of a broiler chicken," "healthy small intestine turkey," "large intestine of a pig with acute diarrhea," etc.

The method comprises training a machine learning algorithm to automatically
20 deploy the analysis software (or the portion of the analysis software formed as a server application), or to automatically deploy an improved version of the analysis software (or an improved version of the portion of the analysis software formed as a server application), wherein the training comprises analyzing a received combinations of digital image of the excretions and measured manifestation of the performance indicator.

25 This can be advantageous because as the number of images in the database and the number of client applications (often corresponding to different animal houses or fattening farms) increases, the training data set grows, and re-training allows for continuous improvement of the analysis software.

According to further embodiments, the analysis software is also designed as a
30 distributed client-server software application. The server application is connected to a plurality of client applications via a network, each of the client applications being operatively connected to an image acquisition unit. Each image capture unit may be located, at least during capture of the images of the excretions, within one of a plurality

of different animal houses or premises in which animals are kept. The server application is adapted to carry out the following procedure for each of the animal houses: Receiving, by the server application from the client application, a message specifying at least one substance or substance mixture currently being administered to the animals of the animal house; Receiving, by the server application from the client application, at least one manifestation of a performance indicator of the animals of the animal house measured or entered by a user via a GUI (of the client application or a feedback application of a slaughterhouse), wherein the manifestation of the performance indicator relates to a time in temporal proximity to the time of administration of the substance or substance mixture; and performing an initial cluster analysis by the server application of the combinations of administered substances or substance mixtures received from each animal house and the received proficiencies of the performance indicator to calculate clusters of animal houses with the same or similar administered substance or substance mixture, wherein an average proficiency of the performance indicator of all animals of each cluster is stored associated with the respective cluster. The average manifestation may be, for example, a median, the arithmetic mean, or otherwise a value calculated from a plurality of manifestations of a performance indicator.

Additionally or alternatively, the server application performs a second cluster analysis of the combinations of administered substances or substance mixtures received from each animal house and the received manifestations of the performance indicator. The second cluster analysis is used to calculate clusters of animal stalls whose animals have the same or similar manifestation of the performance indicator, where the substance or substance mixture administered to the animals of a cluster in the majority of the animal stalls of that cluster is stored associated with the respective cluster. Thus, clusters of animal stalls of similar performance levels are to be formed. By analyzing the feed administered in the majority of the animal house clusters, differences in the mode of action and quality of the feed or feed additive or veterinary preparation can thus be determined. According to embodiments, the analysis software performs the second cluster analysis in such a way that the animal breed and/or the manufacturer of the feed or feed additive is also assigned to each of the clusters formed. This can be advantageous, since different characteristics of the performance and the general health caused by different commercial feed of different manufacturers can be taken from the result of the cluster analysis. Also, animal breeds with different performance or particularly favorable

or unfavorable combinations of animal breed and respectively administered feed or feed additive can be identified by means of the second cluster analysis.

Finally, the results of the first and/or second cluster analysis are sent from the server application to at least one of the client applications for outputting the cluster analysis results to a user.

The cluster analyses outlined above may be advantageous because, without any additional effort worth mentioning, they may be used to test and quantify, for the first time, the effectiveness of certain feed additives and/or veterinary products in practice based on objective empirical data collected in large numbers in commercial animal housing and keeping conditions. Currently, appropriate tests are often tested as part of a regulatory approval process or product development project. However, the number of animals and animal houses tested is often limited and at the hygienic and technical level of universities and research institutions and cannot cover the wide range of different other parameters that may be relevant in practice. In contrast, embodiments of the invention, in particular a distributed client-server system with multiple client applications that are used in different animal herds and which also collects and analyzes performance indicators measured in real terms in at least one slaughterhouse and/or uses them to improve the analysis software, can detect and make use of the effectiveness of certain substances with regard to the performance and health of animals in large numbers and under the real conditions of an animal fattening operation without any particular effort on the part of the animal fattening operations.

The results of the cluster analysis may include suggestions for improving performance parameters, in particular recommendations on medications for predicted diseases and disease symptoms, recommendations on feed or feed/feed additive changes, etc. For example, if the cluster analysis reveals that the 15 farms with the highest manifestations of a performance indicator (e.g., weight gain per time) administer a feed with a feed additive A, or administer the feed of a particular manufacturer, while 11 farms with the lowest manifestations of that performance indicator administer a different feed additive B or of a different feed manufacturer, but the feed is largely identical in composition and other parameters, the server application could, for example, be e.g., be adapted to selectively send an output of the analysis result in the form of a recommendation message to the client applications belonging to the 11 farms with the

poor performance values. The recommendation message may include a recommendation to switch to feed additive A or the better feed manufacturer.

In another aspect, the invention relates to a storage medium on which computer readable instructions are stored in the form of analysis software. The analysis software is adapted to carry out a method comprising: Inputting at least one image to analysis software, wherein the at least one image is a digital image which depicts excretions from one or more of the animals; performing an analysis of the at least one image by the analysis software; outputting, by the analysis software, a recommended action suitable for maintaining or improving the current physiological condition of the animals, the recommended action being dependent on a result of the analysis of the at least one image; and/or outputting, by the analysis software, a predicted manifestation of a performance indicator of one or more of the animals, the performance indicator being a physiological parameter, a disease symptom, or a disease, the predicted manifestation being dependent on a result of the analysis of the at least one image.

The storage medium may be a volatile storage medium or a non-volatile storage medium. In particular, the storage medium may be an electronic storage medium storing information in or based on electronic (semiconductor) devices. To physically store the information, different mechanisms are used, e.g., in the case of volatile memories, DRAM, dynamic RAM (dynamic random access memory) or SRAM (static random access memory), and in the case of non-volatile memories: ROM (read only memory), PROM (programmable read only memory), EPROM (erasable programmable read only memory), EEPROM (electrically erasable programmable read only memory), Flash EEPROM (e.g., USB memory sticks) and others. Technical aids are also required to read electronic storage media. The end user therefore usually receives the electronic storage media not as individual memory chips, but already as a combined product: in the case of DRAM for use as main memory in computers or peripheral devices, several memory chips are combined on one memory module. Flash memories, which are popular for storing multimedia data in mobile applications, come in a variety of packages, usually in the form of memory cards or USB memory sticks, which also contain controllers in addition to the actual memory module. The same applies to solid-state drives, which also use flash memory but come in a different device design with different interfaces. In this context, a storage medium also includes a network of several storage media that are connected to each other via a network.

In another aspect, the invention relates to an electronic system for keeping animals. The system includes a distributed or non-distributed computer system coupled to an animal housing image capture unit. The computer system includes analysis software and a database. The animal house image capture unit is configured to capture at least one
5 image which depicts excretions from one or more of the animals. The analysis software is adapted to carry out a procedure comprising: Storing the at least one captured image in the database; inputting the at least one captured image to the analysis software; performing an analysis of the at least one image; outputting, by the analysis software, a recommended action, which is suited for maintaining or improving the current
10 physiological condition of the animals, the recommended action being dependent on a result of the analysis of the at least one image; and/or outputting, by the analysis software, a predicted manifestation of a performance indicator of one or more of the animals, the performance indicator being a physiological parameter, a disease symptom, or a disease, the predicted manifestation being dependent on a result of the analysis of
15 the at least one image. Optionally, the distributed or non-distributed system may also include one or more sensors mounted in an animal house or stable in which the animals are kept. The sensors are adapted to collect and transmit measured values to the analysis software.

According to embodiments, the computer system is a distributed computer system
20 comprising a server computer and one or more client computers. The analysis software is configured as a distributed client-server software application, wherein a server application is installed and/or instantiated on the server computer system and a client application is installed and/or instantiated on each of the one or more client computers. The distributed computer system further comprises a slaughterhouse computer system
25 operated by a slaughterhouse and coupled to a slaughterhouse image capture unit. The slaughterhouse computer system includes a feedback application. The slaughterhouse image capture unit is configured to capture images depicting the gastrointestinal tract of one or more of the animals after slaughter thereof and provide the images to the feedback application.

30 The feedback application is adapted to transmit the captured gastrointestinal tract images to the server application over the network for storage of the gastrointestinal tract images in the database of the server application. The server application is adapted to carry out a method comprising: Receiving at least one digital image of excretions from one or

more of the animals from the at least one client application, and storing these images in the database; Receiving at least one manifestation, measured or entered by a user via a GUI (of the client application or the feedback application), of a performance indicator of the animals whose excretions are imaged in the at least one received image from the client application or from the feedback application, wherein the manifestation of the performance indicator is in particular images of the gastrointestinal tract after slaughter of the animals. Preferably, the manifestation of the performance indicator relates to a point in time in temporal proximity to the acquisition point in time of the at least one digital image of the excretions; training a machine learning algorithm to automatically provide an improved version of the analysis software or from an improved version of the server application, wherein the training comprises analyzing the received combinations of digital images of the excretions and the received manifestations of the performance indicator. Excretions images and manifestations of the performance indicator relating to the same animals, or at least to animals of the same animal house, are here combined, that is, associated with each other.

In another aspect, the invention relates to a mobile robot, in particular adapted for keeping and/or monitoring animals. The robot includes a motorized unit configured for autonomous or semi-autonomous movement of the robot within an animal house or stable in which the animals are kept. The mobile unit may comprise, for example, one or more wheels or tracks.

The robot includes an image capture unit configured and oriented to capture at least one image of excretions from one or more of the animals. For example, the robot may move according to a dynamically calculated or pre-determined and stored path of movement within the animal house or terrain, with the image capture unit pointed at the ground and capturing a digital image of the ground of the animal house or terrain at regular intervals, such as every 30 seconds. The robot further includes a network interface, e.g., an interface for exchanging data via the Internet, and an image capture unit, e.g., a camera. The robot includes one or more processors and a storage medium on which robot software is stored. The robot software may be, in particular, an analysis software or a client application that is part of an analysis software with server-client architecture. The robot software is adapted to execute, alone or in interoperation with a server connected via a network (and a server application instantiated thereon), a method comprising: acquiring at least one image by the image acquisition unit, the at least one

image being a digital image which depicts excretions of one or more of the animals; inputting the digital image to the robot software; performing an analysis of the received image by the robot software; outputting, by the robot software, a recommended action, which is suited for maintaining or improving the current physiological condition of the animals, the recommended action depending on a result of the analysis of the at least one image; and/or outputting, by the robot software, a predicted manifestation of a performance indicator of one or more of the animals, the performance indicator being a physiological parameter, a disease symptom, or a disease, the predicted manifestation depending on a result of the analysis of the at least one image. The recommended action and/or the predicted manifestation is output to a user via a display device of the mobile robot or via a data processing device connected to the robot via a network, for example, via a display of a smartphone of a user who has registered his smartphone with the robot software.

In another aspect, the invention relates to a combination of a feed additive with an indicator substance and a distributed or non-distributed storage medium with analysis software as described for embodiments of the invention. The indicator substance is a substance that causes a coloration in the excretions of the animals that depends on physiological conditions in the metabolism of the animals. The analysis software is adapted to predict the manifestation of the performance indicator and/or calculate the recommended action based on visual characteristics of the excretions of animals which ingested the indicator substance prior to the taking of the at least one image with the feed or drinking water.

As used herein, a "camera" means a photographic apparatus capable of recording or transmitting via an interface static or moving images on a photographic film or electronically on a magnetic video tape or digital storage medium. An analog photographic device may be a camera, but preferably a smartphone camera is used. The image capture unit or camera can further be connected to light-emitting sources as these are present in a commercially available smartphone anyway (flash light unit and / or smartphone display) or special lighting units, which may be commercially available as additional devices, such as lasers with defined wavelength, IR light sources, and / or UV light sources. Preferably, the analysis software or a part thereof designed as a client application includes an illumination function designed to sequentially illuminate the excretions in a defined manner with light of two or more different wavelength ranges. In

particular, if a fluorescent indicator substance has been administered to the animals, the light source may be adapted to emit light at a wavelength that excites the fluorescent dye to fluoresce.

As used herein, "analysis software" means software that may be distributed across multiple storage locations or stored in a single storage location and that is adapted to carry out an analysis of at least one or more digital images and optionally other data to calculate one or more analysis results.

A "computer system" is understood here to mean the entirety of the hardware & software components of a data processing system. In this context, the hardware and software components may be in the form of a monolithic computer system ("standalone" computer system, e.g., desktop computer, smartphone, notebook, server computer) or in the form of a distributed computer system (cloud computer system, distributed computer system with a server computer system and one or more client computer systems).

A "performance indicator" is a parameter associated with an animal or livestock that includes information regarding the performance, e.g., health, of that animal or livestock. For example, a performance indicator may be a physiological parameter (e.g., weight, growth rate, blood hemoglobin content), a disease symptom (e.g., bloody diarrhea, watery diarrhea), or a disease (e.g., coccidiosis, clostridiosis).

A "color reference object" is an object of any shape that includes one or more predefined areas with different colorations and/or textures associated with the areas. Preferably, the size of the object is such that the object is not substantially larger than the excretions of the animals, so that an image of the excretions can be easily obtained with a cell phone camera, which also images a color reference object positioned in close proximity to the excretions. For example, the color reference object may be essentially two-dimensional and have a length of 0.5 to 10 cm and a width of 0.3 to 5 cm.

A "GUI" is a "graphical user interface."

A "sensor" is a technical component that can qualitatively or quantitatively measure certain physical or chemical properties (physically, e.g., amount of heat, temperature, humidity, pressure, sound field quantities, brightness, acceleration, or chemically, e.g., pH, ionic strength, electrochemical potential) and/or the material composition of its environment as a measurand. These quantities are detected by means of physical or chemical effects and converted into an electrical signal that can be further processed.

As used herein, "excretions" means solid, liquid or viscous excretions of animals, in particular solid, liquid or viscous excretions.

As used herein, "predefined rule-based software" means knowledge-based software that is adapted to carry out rule-based reasoning. Rule-based software includes
5 a set of rules (also called a rule repository) and a rule interpreter (also called an inference engine or rule engine). The rules are in the form: IF ... THEN ... OTHERWISE (IF THEN ELSE).

According to one embodiment, rule-based analysis software may process a received digital image which depicts excretions from animals, for example, as follows, and then apply rules to the processed image: First, the digital image received as an rgb image
10 is decomposed into three separate monochromatic images, hereafter referred to as R, G, and B- images, where the R image selectively includes intensity values of the red image channel, the G image selectively includes intensity values of the green image channel, and B selectively includes intensity values of the blue image channel. In a next step, the intensity values of the three images are each normalized separately. For this purpose, for
15 example, the maximum intensity values measured in each of the respective images, which typically range from 0 to 255, can be mapped to another normalized intensity scale of predefined size, for example 0 to 100. The normalization can alternatively or additionally be performed based on the colors contained in a color reference object mapped to the received rgb image. For example, the color reference object may include a red spot, and
20 the color-specific intensity normalization may be performed such that the highest pixel intensity measured in the r image corresponds to the pixel intensity of that red spot. The color normalization can also be performed by analysis software variants that are not rule-based, e.g., also by analysis software variants that are based on a machine learning approach. In the next step, one or more rules can then be applied to the normalized R, G
25 B images: IF the average intensity calculated over all pixels of a normalized image in each case exceeds a minimum value of 50 for at least the G image or the B image AND the corresponding average value of the R image is below 20 THEN exclude "bloody diarrhea in the rectum" as a candidate for a distinct performance indicator. In other words, this rule implies that images having a certain minimum overall brightness selectively in the
30 green and/or blue light spectrum, but not in the red light spectrum, cannot be considered indicative of bloody diarrhea in the rectum, since such would be accompanied by red staining of the stool. Evaluation of the brightness values of the green and blue image

channels is important because the absence of a signal in the R-scan could also be due to overall insufficient brightness of the image.

According to an alternative color normalization method, the intensity value of each pixel in each of the R, G, and B images is divided by a value K, where K is a value derived from the color reference object. For example, the color reference object may have a red color range FBR, a blue color range FBB, and a green color range FBG, and K may be the sum of the three maximum high intensity values I contained in the three color ranges. K can thus be calculated from $I_{\max_FBR} + I_{\max_FBB} + I_{\max_FBG}$.

For example, a pixel $P_{x-Rnorm}$ of the normalized R image would have the normalized intensity value $I_{\text{pixel-P}} / I_{\max_FBR}$. A pixel $P_{x-Bnorm}$ of the normalized B image and would have, for example, the normalized intensity value $I_{\text{pixel-P}} / I_{\max_FBB}$. A pixel $P_{x-Gnorm}$ of the normalized G image and would have, for example, the normalized intensity value $I_{\text{pixel-P}} / I_{\max_FBG}$. A pixel P_{x-rgb} of the normalized rgb image would have, for example, the normalized intensity value $I_{\text{pixel-P}} / K$.

The rules are preferably combined with various image analysis functions that, for example, detect specific objects and structures. For example, various image analysis methods known in the prior art can detect lines or spheres (gaseous inclusions). Corresponding rules could then be: IF at least three spherical inclusions per cm² of imaged floor area were detected in the course of image analysis, THEN assign an increased probability of occurrence to all candidates for a distinct performance indicator associated with flatulence. The IF part of the rule is also called the premise, and the THEN part is called the conclusion.

For example, it has been observed that when animals are ill with, for example, diarrhea or coccidiosis, small amounts of blood or body salts or tissue excretions are passed in the stool at a very early stage of the disease. The iron-containing hemoglobin contained in the blood is oxidized and increasingly changes the color of the stool to dark, later black stool. This transition is gradual and, according to embodiments of the invention, is used as a basis for generating a rule or is very likely to be a relevant visual feature used by an analysis algorithm trained on a corresponding training data set to perform the image analysis described herein. The "black content" of the excretions is thus used by the analysis software as an indication of the presence of blood in the excretions and of the presence of diseases that may condition this feature. According to embodiments of the invention, for further optimization and structuring of the image

details, further steps are performed during image acquisition such as illumination of the excretions during image acquisition by a light source. The light source may be, for example, a simple flash light source, a white light source, a yellow light source, an infrared light source, a light source that emits fluorescent light and excites excretions containing a fluorescent indicator substance with a corresponding spectral excitation frequency to emit a light signal, a halogen vapor lamp, or more generally a light source for light in a defined short or long wavelength frequency range. Several different light sources may also be used sequentially, or illumination with light of different wavelengths may be provided sequentially by the same light source, the goal being to capture in the images as much detail as possible of the intestinal function affecting the appearance of the excretions.

In a further step, the current day electronic details, e.g. the RGB values of the image capture are compared with the same electronic details of the past e.g. 5 or 7 days in a statistical procedure, e.g. discriminant analysis, in order to prove a statistically provable deviation or identity of the current measured value from the measured values of the past of exactly this stable and this animal breed and this feeding at exactly that, the current time, etc.

In a further step, the production technical measured values occurring in the daily routine are also compared for normality or abnormality in order to refine the statement of the image - measured value. For example, increased water consumption at the time of abnormality of the image results may indicate the onset of diarrhea, which in itself would occur even in hot weather without reference to future health risks. A decreased feed consumption determined from the daily readings of machine or manual feeding combined with abnormal image - readings of the excretions in turn combined with increased water consumption, indicates with high probability an emerging disease with a febrile background, often a bacterial disease of e.g. respiratory disease or colisepsis. If treated early, little antibiotics and hardly any loss of performance can be expected. If detected too late, these diseases lead to high mortality, high use of antibiotics and reduced quality of the slaughtered animals.

Optionally, the rule-based analysis software can include a control module that is designed to adjust the weighting of the rules of the rule database after receiving further data, in particular feedback data from slaughterhouses, so that the analysis result predicts these feedback data as accurately as possible based on the recordings of the excretions.

Cluster analysis is understood herein as a method for discovering similarity structures in data sets. In particular, the data sets may comprise data sets of mutually associated data, where the mutually associated data may include, in particular, images of excretions from animals, empirically collected manifestations of performance indicators of these animals, measured values from sensors in animal houses, and substances administered to the animals. The groups of "similar" data sets found in this way are called clusters, and the group assignment is called clustering. The similarity groups found may be graph-theoretic, hierarchical, partitioning, or optimizing. According to embodiments of the invention, the analysis software or parts of the analysis software, in particular the server application, includes one or more cluster analysis algorithms or an interface to corresponding third-party programs. For example, the R programming language of the GNU project provides class libraries that include, among other things, cluster algorithms. According to one embodiment, k-Means is used as a cluster algorithm.

15 **Short description of the figures**

In the following, embodiments of the invention are described in more detail only by way of example, and reference is made to the drawings in which they are included. It is shown:

20 Figure 1 A computer system with analysis software for monitoring the health of animals in an animal house;

Figure 2 a computer system as in Figure 1, which is designed as a smartphone;

Figure 3 a distributed computer system with analysis software designed in the form of a client-server architecture;

25 Figure 4 a distributed computer system as in Figure 3, comprising several client computer systems;

Figure 5 a flowchart of an animal keeping process;

Figure 6 a block diagram of a mobile robot for animal health monitoring;

Figure 7 a distributed computer system as in Figures 3 and 4, respectively, further comprising a computer system of a slaughterhouse with a feedback application;

30 Figure 8 3 photos of excretions from turkeys suffering from an acute clostridial infection;

Figure 9 2 photos of excretions from turkeys suffering from acute colisepsis (sepsis caused by *Escherichia coli*);

Figure 10 a photo of droppings from a turkey suffering from acute coccidiosis;

Figure 11 a photograph of droppings from a broiler suffering from acute co-
infection of clostridia and coccidia; and

Figure 12 a photograph of excretions from a broiler chicken suffering from an acute clostridial infection.

Detailed description

10

The following descriptions relate to photographs from a poultry broiler house, as used by way of example as an input image for the analysis software in accordance with embodiments of the invention described herein. Optionally, further information, in particular analog and digital measured values and metadata from the house technology
15 (feeding, water supply, ventilation, harmful gas detection) can be used as automatic and/or manual inputs for the analysis software. Preferably, according to embodiments of the invention, the analysis software is designed to predict the manifestation of one or more performance indicators. In particular, these performance indicators of analysis software used to monitor poultry houses or housing facilities include major diseases such
20 as clostridiosis, coccidiosis, pigs dysentery, and salmonellosis. Depending on the type of animal the analysis software is to be used to monitor, the selection of performance indicators considered by the analysis software may vary and depends, depending on the implementation variant, on the defined rules or training data set on which the analysis software is based. Analysis software for monitoring pigs, calves, piglets, cows, beef cattle
25 include, for example, swine/calf salmonellosis, swine *Lawsonia* disease, calf cryptosporidiosis, and others. According to some embodiments of the analysis software, it is also designed for universal use in animal houses and holding facilities for both poultry and mammals and covers a correspondingly broad set of performance indicators. The following photographs show excretions from broilers and turkeys, but the analysis
30 software can also be designed (trained or explicitly programmed) in an analogous manner to process corresponding images of excretions from calves, piglets, and/or pigs without explicitly picturing and explaining these embodiments in the following.

Figure 1 shows a computer system with analysis software 108 for monitoring the health of animals 132 of an animal house 130. The animal house may be, for example, a large house of a fattening farm for broilers, turkeys, pigs or cattle. Especially in large fattening operations, the risk of spreading infectious diseases and the associated economic damage is high. The animal house contains a large number of animals, typically of the same animal species, indicated here by the symbol "A". One or more employees 138 of the livestock operation periodically inspect the livestock house, such as to check that the nozzles of the watering system are still permeable, that the bedding is fresh, and/or that sufficient feed is available at the feeding stations. Preferably, the worker 138 carries an image capture unit, for example in the form of a camera of a smartphone 142. The smartphone is preferably connected to the Internet 136 via a network connection, in particular the mobile network and/or via a local WLAN connection.

Furthermore, the distributed computer system illustrated in Figure 1 includes a further computer system 100, which may be, for example, a server computer system or a normal desktop computer system of a further user 116. The further user 116 may be, for example, a trained employee who is to monitor the health of the animals of one or more animal houses of the fattening operation, and who is not necessarily on site, i.e. in the vicinity of the animal house 130. The computer system 100 includes one or more processors 106, typically also includes a display 112, and a network interface 114 by which it is connected to a network 136. It also includes a storage medium 104, typically a hard drive, that includes a plurality of images 102 of excretions from the animals 132. Preferably, the images 102 are stored in a database, particularly a relational database. This database may include other data, in particular measured values 110 from sensors 134, which are optionally located within or in close proximity to the animal house 130. The sensors may be thermometers, for example.

According to one embodiment, the sensors are sensors that measure the amount of feed or drinking water currently administered or administered over a period of time. This can be beneficial, as reduced appetite or increased thirst can be early signs of an infectious or diarrheal disease. According to another embodiment, the sensors may include sensors to detect the ammonia content of the air. Diarrheal disease is often associated with increased excretion of protein, which is then converted to ammonia in the stall litter and is received by the analysis software as a measured value and evaluated alongside the visual parameters of the excretions during analysis to provide a particularly

high level of analysis and prediction accuracy by combining the visual characteristics of the excretions and the ammonia content of the air.

In addition, the storage medium 104 includes analysis software 108 that is adapted to access the images 102 to specify them as well as optionally further available predictive data, such as the measured values 110 or animal-related metadata (such as the currently administered substance, i.e., animal feed type, feed additives, medications, etc., their dosage or administration method).

In the simplest case, the user's smartphone 138 does not include a client application that is interoperable with the analysis software 108. However, the smartphone includes the smartphone camera and associated camera software already integrated into virtually all smartphone models today. The user can use the already existing software for taking photos by means of a smartphone to take several pictures of excretions of the animals in the course of regular inspection walks, i.e. typically once or several times a day. Preferably, the images of the excretions are taken at several different locations in the animal house. Subsequently, the user 138 may transmit the captured images to the computer system 100 via the network 136. For example, the user may send an email to an email address of the user 116 for this purpose, which email includes the images of the excretions as an attachment. The user 116 may then save the images to the database so that the analysis software can access the images. Preferably, the images 108 of the excretions are stored with a time associated therewith that at least approximates the time at which the images were captured.

The user 116 may access the analysis software 108 after the current images of the excretions have been stored in the database. The analysis software may be implemented in any common programming language, such as Java, C++, C#, and others. The analysis software reads all images of the animals' excretions taken and stored in the database within a predefined time period of, for example, one week, and uses these as input in a subsequent analysis step. Optionally, sensor readings 110 and metadata stored in the database associated with the images 102 may also be read by the analysis software and evaluated in the analysis. In this regard, the measurement data and/or metadata are stored in the database associated with those images 102 that were captured at a time that is in temporal proximity to the capture of the metadata or measurement values.

In some embodiments, the analysis by the analysis software 108 includes a calculation of a recommended action. A recommended action is an action to be

performed manually or automatically that is suitable for maintaining the current physiological state of the animals or improving the current physiological state of the animals. The calculation of the recommended action is performed as a function of the images 102 read by the analysis software and, if available, other data, for example, measured values 110 and/or information on currently administered substances. Additionally or alternatively, the analysis by the analysis software comprises a prediction of a manifestation of a performance indicator of one or more of the animals 132 in the animal house 130. For example, the analysis software may be configured such that the prediction relates to a specific future moment calculated from the current moment of the analysis, such as a moment 2 or 3 days in the future. Also, with respect to the recommended action, it may be an action that is recommended to be performed at a future moment, for example, 2 or 3 days from the time the analysis is performed. However, it can also be an action that is recommended to be performed immediately. The exact timing of the recommendation depends on the type of action and on the implementation of the analysis software, in particular, therefore, on the explicitly specified rules (in the case of a rule-based system) or on the nature and annotation of the training data set used to create the analysis software using machine learning.

Preferably, both types of computation or prediction are performed in the course of an analysis. It is possible that as a result of the analysis, no action is recommended to be taken because the current and predicted performance indicators are good so no action is required. In some embodiments, the user may also specify via a GUI, or it may be specified in a configuration file, whether the analysis software should only calculate and output a recommended action, or alternatively calculate and output a future manifestation of a performance indicator, or both.

The output may be provided, for example, via the display 112 of the computer system 100 to the user 116 so that the user 116 can take appropriate action to maintain or improve the health of the animals. The performance indicator may be, for example, the presence of a particular disease in one or more animals 132 in the animal house.

For example, the analysis software may be adapted to calculate the presence and future severity of various diseases based on the images 102 of the excretions of the animals. The diseases are in particular coccidiosis (infestation with coccidia), clostridiosis (infestation with clostridia), diarrhea or sepsis caused by various bacteria such as in particular coccidia, clostridia, *Escherichia coli*, and/or salmonella).

For example, in the event that the analysis software detects a current infestation of coccidia in some broiler chickens and predicts a population-wide outbreak of the disease in 2-3 days, the analysis software provides an alert message to the user 116 via the screen 112. The warning message includes an indication that a population-wide outbreak of coccidiosis is expected in the animal house 130 in the next 2-3 days.

The causative agent of coccidiosis, *Eimeria tenella*, causes bleeding inflammation of the small intestine or appendix, especially of chicken chicks 2 to 6 even to 8 weeks of age. Coccidiosis is accompanied by bloody diarrhea, which in the case of appendiceal coccidiosis can result in a mortality rate of up to 80 percent due to hemorrhage.

Coccidiosis infection of the small intestine also occurs primarily in young animals, but also in debilitated old animals. It manifests itself in inflammation of the small intestine, in which bleeding and tissue breakdown may occur. Responsible for this is the occurrence of various coccidia species, such as *Eimeria necatrix* and *Eimeria tenella*, *Eimeria brunetti* and *Eimeria gallopavonis*. The latter two strains cause mucopurulent diarrhea but rarely bleed. The mortality rate for small and rectal coccidiosis is 30% due to fluid loss.

Based on the characteristic stool appearance (highly dark-colored excretions due to blood/oxidized hemoglobin in the case of appendiceal coccidiosis or the muco-thin consistency of the excretions in the case of small bowel coccidiosis), the analysis software can detect and predict the current presence or a probable future outbreak of coccidiosis and its subtypes. Consideration of other parameters, in particular measured values such as the amount of feed consumed per animal or per house per day, are also considered in the analysis according to embodiments of the invention. Lack of appetite, which is accompanied by reduced feed intake, can be taken into account as a further measurement parameter value and is an indication of a possible coccidia infection in chickens.

Bloody diarrhea in chicks is most often due to coccidial infection, whereas diarrhea such as that seen in small and rectal coccidiosis may also be due to feeding. Therefore, it may be beneficial to also include metadata in the analysis. These may include, for example, the type of animal, the age of the animal, the type of feed currently being administered, and other information. For example, the analysis software 108 may be configured to display a GUI via the display 112 through which the user 116 may enter said metadata so that it can be stored in the database along with the images 102 and also analyzed by the analysis software 108. Alternatively, or in addition to the GUI, the analysis

software may have an interface through which said data may also be automatically received from a storage medium, from other software (e.g., animal house management software), and/or from sensors or animal house equipment (e.g., feeding and water systems).

5 The message output by the analysis software may preferably include a recommended action in addition to the prediction of clostridial infestation, for example, an indication that coccidial medications should be added to the feed or drinking water immediately. Optionally, the message could also include several recommended actions, for example, indicating that additional administration of multivitamin and mineral
10 supplements is recommended to compensate for electrolyte loss and to achieve the fastest possible recovery. Because coccidia are exceptionally environmentally stable and can survive in the environment for many years, the message may also include a recommendation to disinfect the affected animal house.

 Thus, the "manifestation" of the performance indicator "coccidiosis disease" may
15 be a more detailed characterization of the disease (appendiceal coccidiosis or small intestinal/terminal coccidiosis) and/or a prediction of the severity of the disease at a given time, since the particular composition of the pathogens has an influence on both the severity of the disease and the consistency of the excretions.

 Figure 2 illustrates a computer system 200 which, like the computer system 100 of
20 Figure 1, includes analysis software 108. However, the computer system 200 is a portable computer system, such as a smartphone with an integrated image capture unit 140, that the user 138 carries with him or her during his or her inspection walk through the animal house. The portable computer system 200 includes a storage medium 202 on which the analysis software 108 and the current and past images 102 of the excretions of the
25 animals are stored, for example in the form of multiple records of a relational database. Optionally, the computer system may have an interface 210 through which it may receive sensor readings 110 from one or more sensors 134. The sensor readings 110 may then also be stored on the storage medium 202 or in the database located thereon. The computer system has one or more processors 204, a display device 206, and preferably
30 also a network interface 208. The sensor interface 210 may be, for example, a near-field communication interface such as a Bluetooth interface or an RF (radio frequency) interface. However, it is also possible that the sensor interface 210 is a network interface 208 or that no measured values 110 are received at all. The analysis software 108 is

designed as so-called "standalone" software applications, i.e., even in the event that no network connection is available, the software 108 can independently receive the images 102 taken by the camera 140 of the excretions of the animals 132 and evaluate them in the course of an analysis. The result of the analysis, a recommended action and/or a predicted manifestation of a performance indicator of the animals, is then output by the analysis software 108. The output may be provided to the user of the computer system 200, for example, via the display 206. The embodiment shown in Figure 2 has the advantage that even in animal houses or areas where no network connection or mobile phone connection is available, a user of the computer system 200 is enabled to detect diseases or other health problems of the animals at an early stage and to take suitable countermeasures in a simple and intuitive manner and without special training, by simply taking several pictures of excretions of the animals with his smartphone camera 140 and entering them into the analysis software 108 for analysis. Preferably, the analysis software 108 includes functionality for controlling the camera 140 so that the camera functionality is integrated into the analysis software, making it easier to use.

Figure 3 illustrates a distributed computer system with analysis software that is in the form of a client-server architecture. This means that some of the functionalities of the analysis software 108 are now handled by a server application 302 installed and/or instantiated on a server computer 310, and that some other functionalities of the analysis software 108 are handled by a client application 304 installed and/or instantiated on a client computer system 300. The client computer system is preferably configured as a portable computer system, for example, a smartphone or tablet computer of a user 138. The client application 304 is interoperable with the server application 302, meaning that both applications are adapted to exchange data and control commands in a coordinated manner over a network 136 to interactively provide the analysis functionality of the analysis software 108 described previously.

Preferably, the server application 302 is adapted to interact with a plurality of client applications, wherein the data exchange is session bound and a client application does not have access to the data that other client applications exchange with the server application. Typically, prior registration of the users of the respective client applications with the server application is required before the analysis functionality can be executed.

Typically, the analysis software functionality is distributed between the client application and the server application such that the client application 304 is adapted to

control an image capture unit 140 that is part of or operatively connected to the client computer system 300 to cause it to capture one or more images of excretions from the animals 132. For example, the client application 304 may have a graphical user interface that allows the user 138 to capture one or more images of selected locations of the floor
5 of the animal house via the camera 140 and transfer the images from the camera to the client application 304. Optionally, the captured images may be stored locally on the storage medium 202 of the client application. Further, in some embodiments, the client application 304 may be configured to receive sensor readings 110 from one or more sensors 134 and store them locally. This may be done via a network interface and/or a
10 near-field interface 210, as previously described. Alternatively, or in addition, the GUI of the client application 304 may include a plurality of input fields that allow the user 138 to enter metadata relating to the animals or animal housing into the client application. In particular, this metadata includes animal species, age of the animals, medications currently administered, feed and feed additives, amount of feed or water currently
15 administered per animal or animal house per day.

The server application is configured to receive the images 102 over the network 136 from the client application (or multiple client applications), and preferably store the images 102 in a database of the server computer. Preferably, the storage is such that an identifier of the client application, which may also be in the form of a user ID or animal
20 stall ID, and an approximate time of capture of the images 102 are stored associated with the received images 102. The server application then performs an analysis of the received images 102 in response to a trigger mechanism. The trigger mechanism may be, for example, the receipt of the images or a user interaction with the server application or a control command from an automatic timer (for example, "cron-job"). Preferably, not only
25 the images currently received by the client application 304, but all images of the excretions of the animals received by that client application within a predefined time period are analyzed. In some embodiments, the client application 304 and/or the server application 302 may have a filtering function that filters out and does not forward to the server application, or does not consider in the analysis, images that have too low a
30 resolution or that have too small a portion of the image that actually represents the excretions.

In some embodiments, all measurements may be received first by the client application and then transmitted over the network to the server application. In other

embodiments, the server application is adapted to receive sensor readings 110 from the sensors of an animal house or enclosure associated with the client application 304 via a network interface 114. It is also possible for the server application to receive a portion of the sensor readings 110 from the client application and another portion directly from the sensors 134 via the network interface 114. For example, an association of sensor readings 110, metadata that may also be received, and digital images 102 with a particular client application and/or with a particular animal house may be accomplished via a common client application ID that is transmitted to the server application as part of both the images 102 and the metadata and the sensor readings.

Figure 4 is a block diagram of a distributed computer system, which, like the distributed computer system already shown in Figure 3, includes a client computer 300.1 and a server computer 310. The analysis software 108 is in the form of a client-server architecture. The distributed system includes other client computer systems 300.2, 300.3, each of which is associated with other client applications 304.2, 304.3, other animal houses 130.2, 130.3, and other users 404, 406, as appropriate.

This embodiment has the advantage that empirical data, in particular image data of excretions of the kept animals, measured values recorded by sensors, observed manifestations of performance indicators as well as metadata (such as animal feed, feed additives, animal species, animal age and the like) can be stored centrally in a database of the server computer 310. Preferably, the server application includes advanced analysis capabilities, particularly cluster analysis techniques. By applying various cluster analysis methods to the available data, which in particular include image data of excretions, measurement data, metadata as well as data (in particular image data) of observed manifestations of performance indicators, it is possible to determine groups (so-called clusters) of animal houses of similar animal performance levels. A comparison of the currently used feeds, veterinary preparations and feed additives administered to the animals in the individual clusters makes it possible to determine whether a particular substance or feed composition, or even a feed supplier or breeding company, correlates with particularly high or particularly low animal performance. This makes it possible to use objective, empirical data to identify feeds or feed additives or suppliers that have a beneficial effect on animal health for a particular type of animal or for a particular initial situation (for example, suspected infestation with certain pathogens).

Figure 5 a flowchart of a method for maintaining animals. In particular, the method may be used to monitor the health and performance of animals. In a first step 502, one or more images 102 showing excretions from animals 132 are input to analysis software 108. For example, the analysis software may obtain the images directly from a local image capture unit, or read them from a local data store, or obtain them over a network from a client application or a robotic application. It is also possible that the images are transmitted via an email application or, in "real time", via an APP application to the computer on which the analysis software is instantiated, and then semi-automatically transmitted to the analysis software by an email application of that computer. In a next step 504, the analysis software performs an analysis of the input images to obtain an analysis result. The analysis result may suggest one or more recommended actions suitable to preserve or improve the current physiological state of the animals, and/or a predicted manifestation of a performance indicator of the animals. In this context, the analysis result depends on the received images of the excretion and, if available, on measured values 110 and/or further metadata. The metadata may include substances or mixtures of substances administered to the animals at the time of analysis. Preferably, the analysis refers to images and the optional measurement values and/or metadata received within a defined period of time prior to the analysis, e.g., within 7 days prior to performing the analysis. Finally, the recommended action is output in step 506 and/or the predicted manifestation is output in step 508. Thus, the outputted analysis results may include either the recommended action or the predicted manifestation of the performance indicator, or both. The output may be provided to a user, for example, via a GUI of the analysis software.

Figure 6 illustrates a block diagram of a mobile robot 600 for animal health monitoring. For example, the robot 600 may be used in an animal house 130 as described with respect to Figures 1, 2, and 3. For example, the robot may be used to perform or accompany some of the work of workers 138, particularly some monitoring walks. The robot includes one or more processors 604 and optionally a display device 606 through which a user may interact with the robot. Also optionally, the robot includes a network interface 608 to exchange data with a network, particularly the Internet. For example, the network interface 608 may be used by the robot software 108 to send images 102 of excretions from the animals in the animal house captured by one or more cameras 140 of the robot 600 to a server application 302 via the network 136. The robot software 108

may be analysis software, as previously described for embodiments of the invention. In particular, the analysis software is adapted to analyze the images 102 captured by the camera 140 and output a recommended action and/or a predicted manifestation of a performance indicator. For example, the output may be provided to a user via a GUI using the display 606. The robot may include a storage medium 602 on which the captured images 102 are stored locally. Optionally, the robot may further include a sensor interface 612 to one or more sensors 134 of the animal house. In particular, the sensor interface 612 may be a near-field communication interface, for example a Bluetooth interface or an RF interface. In addition or as an alternative to the sensor interface 612, the robot may also include its own sensors 134, for example, a thermometer for measuring floor temperature, humidity meters, and the like.

The robot includes a motorized unit 610, for example, motorized wheels or tracks, that enable the robot to traverse the animal house in a substantially autonomous manner. The path of traversal may be fixed in the robot software in some embodiments. However, it may also be the case that the path of movement of the robot is not explicitly fixed, but is dynamically calculated by the robot software based on certain optimization criteria in combination with dynamically detected obstacles that are avoided.

In some embodiments, the camera 140 is oriented and positioned at a height such that captured digital images depict an area of the ground near the robot. In some embodiments, the height and/or orientation of the camera is changeable, and the change in height and/or orientation of the camera may be manual and/or automatic. Preferably, the change in height or orientation is automatic and controlled by the robot software 108, which includes a function to analyze the quality of the images captured by the camera 140. If the resolution is too low or the portion of the image that actually shows the excretions of animals is too small, the height and/or orientation of the camera is automatically adjusted so that the next images have a sufficiently large image area showing the excretions in high resolution and sufficient contrast. In addition or alternatively to the height or orientation of the camera, the zoom (optical or software-based) of the camera can also be changed automatically or manually so that the captured images meet the quality criteria of the robot software.

Figure 7 is a block diagram of a distributed computer system 700 as described in Figures 3 and 4, respectively. The distributed system 700 also includes one or more computer systems 710 of a slaughterhouse 714, which are preferably mobile computer

systems. It is also possible that the system 700 comprises further computer systems of further slaughterhouses (not shown here). It is common practice in slaughterhouses for slaughterhouse employees 732 to routinely or randomly check the health of slaughtered animals by performing a post-slaughter inspection of the gastrointestinal tract 750-758 of the slaughtered animals 740-748.

According to one embodiment of the invention, a mobile computer system 710 is associated with an employee 732 of the slaughterhouse. In particular, the mobile computer system 710 may be a smartphone or a tablet computer. The computer system 710 includes one or more processors 714, a display device 720, and a network interface 724. In addition, the computer system 710 includes a storage device 712 having a feedback application 726. Further, the computer system 710 includes an image capture unit 716, such as a smartphone camera. The feedback application 726 is interoperable with the server application 302. For example, it may be a variant of the client application described above that has an additional function of sending images of the gastrointestinal tract of slaughtered animals to the server application instead of or in addition to the images of the excretions. The employee 732 may launch the feedback application 726 and cause it, for example by interacting with a GUI of the feedback application, to take digital images 728 of the gastrointestinal tract 750-758 of freshly slaughtered animals 740-748,132 using the cameras 716. These images 728 may optionally be stored locally on storage media 712. In either case, they are sent over the network 136 from the feedback application 726 to the server application 302. The images 728 represent feedback information in that they provide information about the health status of the animals, particularly as it relates to the gastrointestinal tract, as of the day of slaughter. Thus, the images 728 represent empirically recorded manifestations of one or more performance indicators at a particular time. The images 728 may, for example, be provided with an identifier of the animal house or fattening farm from which they originate, so that they are associated in the database 762 of the server computer with the images 102 of the excretions of the animals of the same animal house or fattening farm a few days before their slaughter by means of this identifier. It is also possible to perform an association of images 102,728 and measurement data and metadata, if available, based on an identifier of individual animals. However, individual animals are often not individually recorded. It has been found that in practice it is also sufficient to perform an assignment of said data in the database 726 based on identifiers of a particular animal house or animal fattening

farms, since the health status of animals in the same animal house is often identical or very similar, being largely determined by the absence or presence of infectious diseases. If a few animals are affected, the entire animal population is usually infected within a few days. Therefore, an exact assignment of images 728 of the gastrointestinal tract of individual animals obtained in slaughterhouses and images 102 of the excretions of individual animals obtained in animal houses is not necessary at the level of individuals. In practice, an association based on a common animal house and a temporal proximity of the acquisition of the images or other data of a few days or hours is sufficient.

The server application 302 is configured, for example, as a machine learning application that is periodically re-trained on a training data set. The training data set is preferably continuously augmented with both images of excretions from animals of one or more animal houses and associated empirically collected manifestations of performance indicators, in particular images taken in a slaughterhouse of the gastrointestinal tract of slaughtered animals. It is also possible that these images are made by the operator of the animal houses. For example, individual animals may die while still in the animal house and be examined more closely by the animal house operator to determine if a contagious disease was the cause of death. On this occasion, images of the gastrointestinal tract of the deceased animals may also be taken and transmitted to the server application 302.

The machine learning software may be, in particular, software based on one or more neural networks. According to some embodiments, the machine learning based analysis software may use existing program libraries, e.g., Caffe, a program library for deep learning, Deeplearning4j (an open source software programmed in Java that is based on a neural network, the Java library ELKI, GNU R, and others.

A machine-learning software is a software that has automatically acquired knowledge based on examples (a training data set) in a learning phase, which this software can apply to solve data processing problems. For example, the (trained) software can be educated and "trained" to automatically recognize images of excretions of animals and optionally additional information linked to these (metadata, measured values), which manifestation a performance parameter of the animals will have or has in the near future or currently and which actions can be helpful to promote or stabilize the health of the animals, so that a drop in performance is prevented or eliminated.

Figure 8 shows three photographs of excretions from adult turkeys suffering from acute Clostridia infection. The thin consistency with vesicular inclusions is striking, indicating diarrheal disease. The excretions are yellow-orange in color, but not black. This is an indication that the diarrhea is watery rather than bloody. Vesicular structures can be detected by the analysis software, for example, by applying algorithms to detect lines, circles, and other geometric objects.

Figure 9 shows two photographs of excretions from adult turkeys suffering from acute colisepsis (sepsis caused by *Escherichia coli*). The consistency of the excretions is also thin-mucilaginous, and the color is white-yellowish, sometimes with a greenish tinge. The yellow color is an indication of a lack of bile or a dysfunction of the pancreas. The greenish color is an indication of infection, in this case with *Escherichia coli*.

Figure 10 shows a photograph of excretions from an adult turkey suffering from acute coccidiosis. Unlike the excretions shown in Figures 9A and 9B, the excretions shown in Figure 10 is uniformly and distinctly green in color. There are no bubble-like inclusions. The green color is indicative of a very advanced infection.

Figure 11 shows a photograph of excretions from a broiler chicken suffering from acute co-infection of Clostridia and Coccidia. The dark color of the excretions is indicative of significant blood loss and oxidized hemoglobin.

Figure 12 shows a photograph of excretions from a broiler chicken suffering from acute Clostridial infection. A comparison of the photos in Figures 12 and 8 shows that the color and consistency of the excretions depend strongly on the animal species in addition to the disease. Therefore, according to preferred embodiments of the invention, the species and/or breed of the animals and preferably also their age is entered into the analysis software alongside the images of the excretions to ensure that the analysis can take this metadata into account.

Reference list

100 Computer system

102 Images of excretions from one or more animals

104 Storage medium

106 Processor

108 Analysis software

	110	Sensor readings
	112	Display
	114	Network interface
	116	User
5	130	Animal house
	132	Animal
	134	Sensor
	136	Network
	138	Animal house controller
10	140	Image capture unit (e.g. camera)
	142	Smartphone
	200	Computer system (smartphone)
	202	Storage medium
	204	Processor
15	206	Smartphone display
	208	Network interface
	210	Sensor interface
	300	Client computer system (smartphone)
	302	Server application
20	304	Client application
	310	Server computer system
	400	distributed system with multiple client computers
	402	user/operator of the server computer
	404	user of the client computer system 300.2
25	406	Client computer system user 300.3
	502-508	Steps
	600	Robot
	602	Storage medium
	604	Processor
30	606	Display
	608	Network interface
	610	motor unit
	612	Sensor interface

- 700 distributed system with client computers and slaughterhouse computer
- 710 Slaughterhouse computer system
- 712 Storage medium
- 714 Slaughterhouse
- 5 716 Image acquisition unit of the slaughterhouse (camera)
- 718 Processor
- 720 Display
- 722 Sensor interface
- 724 Network interface
- 10 726 Feedback application
- 728 Images of the gastrointestinal tract of slaughtered animals
- 732 Employees at the slaughterhouse
- 740-748 Slaughtered animal carcasses
- 750-758 Gastrointestinal tract of the respective carcasses

Patentkrav**1.** Fremgangsmåde til dyrehold (132), omfattende:

- 5 - indlæsning (502) af mindst et billede (102) i en analysesoftware (108), idet det mindst ene billede er et digitalt billede, som afbilder afføringen fra et eller flere af dyrene (132);
- gennemførelse af en analyse (504) af det mindst ene billede med analysesoftware (108);
- 10 - udlæsning (506) af en anbefalet handling, som er egnet til at bevare eller forbedre dyrenes aktuelle fysiologiske tilstand, med analysesoftware, idet den anbefalede handling afhænger af et resultat af analysen af det mindst ene billede; og/eller
- 15 - udlæsning (508) af en forudsagt manifestation af en ydelsesindikator for et eller flere af dyrene med analysesoftware, idet ydelsesindikatoren er en fysiologisk parameter, et sygdomssymptom eller en sygdom, idet den forudsagte manifestation afhænger af et resultat af analysen af det mindst ene billede.

2. Fremgangsmåde ifølge krav 1, ved hvilken de dyr, hvis afføring det mindst ene billede afbilder, er dyr, som inden optagelsen af det mindst ene billede har fået
20 tilvejebragt eller indgivet et fodermiddel eller drikkevand med tilsætning af et indikatorstof, idet indikatorstoffet er et stof, som fremkalder en farvning i dyrenes afføring, som afhænger af dyrenes fysiologiske tilstand, især angreb af dyrene med patogener.

25 **3.** Fremgangsmåde ifølge et af de foregående krav, endvidere omfattende:

- registrering af det mindst ene billede (102) med en billedregistreringsenhed (140), idet billedregistreringsenheden fortrinsvis er valgt fra en gruppe omfattende:
 - 30 • et bærbart kamera, især et smartphone-kamera eller et fotoapparat; eller
 - et i en dyrestald eller et område, hvor dyrene holdes, fast installeret kamera; eller

- et på en mobil robot (600) eller et transportbånd anbragt kamera, idet robotten eller transportbåndet er udformet og placeret til at bevæge sig i en dyrestald eller på et område, hvor dyrene holdes.

5 **4.** Fremgangsmåde ifølge krav 3, ved hvilken registreringen af det mindst ene billede omfatter:

- placering af et farverefERENCEobjekt i rumlig nærhed af den afføring, hvis billede registreres, idet farverefERENCEobjektet har en eller flere forskellige farver, og idet analysesoftwaren er udformet til at anvende
- 10 farverefERENCEobjektets farver ved analysen af det mindst ene billede til normalisering af farverne af den i det mindst ene billede afbildede afføring; idet det mindst ene billede (102) foruden afføringen også afbilder farverefERENCEobjektet.

15 **5.** Fremgangsmåde ifølge krav 3 eller 4, omfattende:

- udsendelse af en styrekommando til en belysningsenhed, som foranlediger belysningsenheden til under optagelsen af det mindst ene billede af afføringen at belyse afføringen med lys fra et eller flere definerede bølgelængdeområder,
- 20 idet belysningsenheden fortrinsvis belyser afføringen sekventielt med lyset fra flere definerede bølgelængdeområder, og idet der under belysningen med hvert af de definerede bølgelængdeområder registreres et eller flere bølgelængdeområde-specifikke digitale billeder af afføringen, og idet analysesoftwaren er udformet til at gennemføre analysen på en bølgelængdeområde-specifik måde selektivt for det
- 25 eller de billeder, som er optaget med lyset fra det pågældende bølgelængdeområde.

6. Fremgangsmåde ifølge et af de foregående krav,

- ved hvilken handlingen skal gennemføres på et handlingstidspunkt, idet
- 30 handlingstidspunktet er et aktuelt tidspunkt eller et fremtidigt tidspunkt ud fra analysetidspunktet; og/eller
- ved hvilken den forudsagte manifestation af ydelsesindikatoren forudsiges for et manifestationstidspunkt, idet manifestationstidspunktet er et fremtidigt tidspunkt ud fra analysetidspunktet.

7. Fremgangsmåde ifølge et af de foregående krav, ved hvilken den anbefalede handling indbefatter en eller flere handlinger, der er valgt fra en gruppe handlinger omfattende:

- tilvejebringelse af et bestemt dyrefoder eller drikkevand;
- 5 - indgivelse af et eller flere medicinske eller ikke-medicinske stoffer i fysiologisk aktiv form til dyrene, især mineraler, vitaminer, medikamenter;
- afslutning af en løbende indgivelse af et eller flere medicinske eller ikke-medicinske stoffer i fysiologisk aktiv form til dyrene;
- 10 - ændring af de fysiske parametre i en dyrestald eller på et områdes, hvor dyrene holdes, især luftfugtighed, temperatur.

8. Fremgangsmåde ifølge et af de foregående krav,

- ved hvilken udlæsningen af den forudsagte manifestation af ydelsesindikatoren og/eller udlæsningen af den anbefalede handling sker til
- 15 en bruger over et bruger-interface i analysesoftware; og/eller
- ved hvilken udlæsningen af den anbefalede handling sker til et elektronisk eller mekanisk system, som er funktionelt koblet til en dyrestald eller et område, hvor dyrene holdes, idet det elektroniske eller mekaniske system er udformet til som svar på modtagelsen af den udlæste handling at
- 20 gennemføre handlingen.

9. Fremgangsmåde ifølge et af de foregående krav, ved hvilken sygdommen er coccidiose, salmonellose, kryptosporidiose, sygdomme fremkaldt af mave-tarm-parasitter, såsom især maveorm eller tarmorm eller encellede patogener, Coli

25 sepsis, lawsoniose, svinedysenteri eller en clostridieinfektion.

10. Fremgangsmåde ifølge et af de foregående krav, ved hvilken dyrene er fjerkræ, okser, får eller svin.

30 **11.** Fremgangsmåde ifølge et af de foregående krav, ved hvilken analysesoftware er en software på grundlag af foruddefinerede regler.

12. Fremgangsmåde ifølge et af de foregående krav 1-9, ved hvilken analysesoftware er en trænet machine-learning-software.

13. Fremgangsmåde ifølge krav 12, endvidere omfattende:

- tilvejebringelse et træningsdatasæt, der indbefatter et stort antal trænings-billeder af afføring fra dyr af samme dyreart som de dyr, die skal holdes, idet trænings-billederne er annoteret med metadata, idet metadataene indbefatter angivelser til manifestation af mindst en ydelsesindikator for det eller de dyr, hvis afføring er afbildet i træningsbillederne, og idet metadataene desuden indbefatter sammensætningen af det foder eller drikkevand, som blev indgivet til disse dyr på tidspunktet for optagelsen af trænings-billederne;
- frembringelse af analysesoftwaren ved træning af en machine-learning-software på træningsbillederne.

14. Fremgangsmåde ifølge et af de foregående krav, ved hvilken det mindst ene billede omfatter et stort antal billeder,

- idet indlæsningen af det mindst ene billede og analysen af det indlæste mindst ene billede foregår regelmæssigt med en frekvens på mindst en gang daglig, idet de i hvert tilfælde indlæste billeder er digitale billeder, som i hvert tilfælde er optaget aktuelt og viser den aktuelle afføring fra et eller flere af dyrene;
- idet analysen i hvert tilfælde foregår selektivt på de af de modtagne billeder, som er optaget inden for et forudbestemt tidsrum før analysetidspunktet.

15. Fremgangsmåde ifølge et af de foregående krav, ved hvilken

analysesoftwaren omfatter tilgang til en database med data over en dyreholders forråd af forskellige stoffer eller stofblandinger, især fodersammensætninger, fodertilsætningsstoffer, drikkevandstilsætningsstoffer, vitaminer, mineraler og veterinærmedicinske præparater, endvidere omfattende:

- kontrol med analysesoftwaren af, om forrådet efter udtagningen af den i overensstemmelse med den anbefalede handling af forrådet udtagne mængde og art af stoffet eller stofblandingen er udtømt med hensyn til dette stof eller denne stofblanding; og
- automatisk udsendelse af en bestillingsmeddelelse med analysesoftwaren, til et elektronisk bestillingssystem hos en udbyder af det udtagne stof eller den udtagne stofblanding over et netværk.

16. Fremgangsmåde ifølge et af de foregående krav, endvidere omfattende:

- indlæsning af mindst en måleværdi i analysesoftwaren (108), idet den mindst ene måleværdi er valgt fra en gruppe måleværdier omfattende:

- 5
 - temperatur af den af dyret afgivne mælk;
 - elektrisk ledningsevne af den af dyret afgivne mælk;
 - staldens temperatur; især standens gulvtemperatur eller lufttemperaturen i nærheden af staldens gulv;
 - staldluftens ammoniakindhold og kuldioxidindhold;
- 10
 - staldluftens fugtindhold;
 - mængde af det pr. dyr eller pr. dyrestald pr. tidenhed i den senest målte tidsenhed afgivne foder;
 - mængde af det pr. dyr eller pr. dyrestald pr. tidsenhed i den senest målte tidsenhed afgivne drikkevand;
- 15
 - gennemførelse af en analyse af den mindst ene måleværdi med analysesoftwaren (108);

idet den anbefalede handling og/eller den forudsagte manifestation af ydelsesindikatoren afhænger af resultatet af analysen af det mindst ene billede og af et resultat af analysen af den mindst ene måleværdi.

20

17. Fremgangsmåde ifølge et af de foregående krav, ved hvilken analysesoftwaren er implementeret som:

- 25
 - en softwareapplikation, der er oprettet på et mobilt computersystem, især en smartphone, idet analysesoftwaren er udformet til at modtage det mindst ene billede af afføringen fra et kamera på det mobile computersystem og eventuelt at modtage metadata og/eller måledata, at gennemføre analysen af det mindst ene billede og udlæsningen af den anbefalede handling og/eller af den forudsagte manifestation af ydelsesindikatoren; eller
- 30
 - en fordelt client-server-softwareapplikation, idet client-softwaren er oprettet på et mobilt computersystem, især en smartphone, og er udformet til at modtage det mindst ene billede af afføringen fra et kamera på det mobile computersystem og sende det til en server-applikation, der er oprettet på et server-computersystem, idet server-applikationen er
- 35
 - udformet til at modtage det mindst ene billede fra client-applikationen, at

5 gennemføre analysen af det mindst ene billede til beregning af den anbefalede handling og/eller af den forudsagte manifestation af ydelsesindikatoren og at sende den anbefalede handling og/eller den forudsagte manifestation til client-applikationen over netværket, og idet client-applikationen er udformet til at udlæse den anbefalede handling og/eller den forudsagte manifestation til brugeren af det mobile computersystem.

- 18.** Fremgangsmåde ifølge et af de foregående krav, ved hvilken
- 10 analysesoftwaren er udformet som fordelt client-server-softwareapplikation, idet server-applikationen over et netværk (136) er forbundet med et stort antal client-applikationer, idet eventuelt også en eller flere feedback-applikationer, som er indrettet på computere på slagterier, er forbundet med server-applikationen over netværket, idet hver af client-applikationerne er funktionelt forbundet med en
- 15 billedregistreringsenhed (140) og er udformet til at sende mindst et billede af afføring fra de dyr, som billedregistreringsenheden har optaget, til server-applikationen,
- idet server-applikationen er udformet til at gennemføre følgende fremgangsmåde:
- modtagelse af mindst et digitalt billede (102) fra hver af client-
 - 20 applikationerne med server-applikationen, idet det mindst ene modtagne billede afbilder afføring fra et eller flere af dyrene (132);
 - modtagelse af mindst et målt eller af en bruger over et GUI indlæst manifestation af en ydelsesindikator for dyrene, idet GUI'et er et GUI til en eller flere af client-applikationerne og/eller et GUI til en eller flere
 - 25 feedback-applikationer, idet feedback-applikationen er en software-applikation på et slagteri, idet manifestationen af en ydelsesindikator især er billeder af mave-tarmkanalen efter slagtingen af dyrene;
 - træning af en machine-learning-algoritme til automatisk tilvejebringelse af en forbedret version af server-applikationen, idet træningen omfatter en
 - 30 analyse af de modtagne kombinationer af digitalt billede af afføringen og målt manifestation af ydelsesindikatoren.

- 19.** Fremgangsmåde ifølge et af de foregående krav, ved hvilken
- analysesoftwaren er udformet som fordelt client-server-softwareapplikation, idet
- 35 server-applikationen over et netværk (136) er forbundet med et stort antal client-

applikationer, idet hver af client-applikationerne er funktionelt forbundet med en billedregistreringsenhed (140), idet hver af billedregistreringsenhederne befinder sig inde i en af et stort antal forskellige dyrestalde,

idet server-applikationen er udformet til for hver af dyrestaldene at gennemføre

5 følgende fremgangsmåde:

- modtagelse af en meddelelse, der specificerer mindst et stof eller en stofblanding, som for tiden indgives til dyrene i dyrestalden;

10 • modtagelse af mindst en målt eller af en bruger over et GUI til client-applikationen indlæst manifestation af en ydelsesindikator for dyrene i dyrestalden med server-applikationen fra client-applikationen, idet manifestationen af ydelsesindikatoren refererer til et tidspunkt i tidsmæssig nærhed af tidspunktet for indgivelsen af stoffet eller stofblandingen; og

15 - gennemførelse en første clusteranalyse af de fra hver dyrestald modtagne kombinationer af indgivne stoffer eller stofblandinger og den modtagne manifestation af ydelsesindikatoren til beregning af clustere af dyrestalde med samme eller lignende indgivne stof eller stofblanding, idet en gennemsnitlig manifestation af ydelsesindikatoren for dyrene i hver cluster af server-applikationen lagres knyttet til den pågældende cluster; og/eller

20 - gennemførelse af en anden clusteranalyse af de fra hver dyrestald modtagne kombinationer af indgivne stoffer eller stofblandinger og den modtagne manifestation af ydelsesindikator til beregning af clustere af dyrestalde, hvis dyr har samme eller lignende manifestation af ydelsesindikatoren, idet stoffet eller stofblandingen,

25 som indgives i flertallet af dyrestaldene i en cluster, af server-applikationen lagres knyttet til den pågældende cluster; og

- udsendelse af resultatet af den første og/eller den anden clusteranalyse til mindst en af client-applikationerne til udlæsning af clusteranalyseresultaterne til en bruger.

30

20. System til dyrehold, omfattende:

- et fordelt eller ikke-fordelt computersystem (100, 200, 300, 310), som er forbundet med en dyrestald-billedregistreringsenhed, idet

computersystemet indbefatter en analysesoftware (108) og en database

35 (762), idet dyrestald-billedregistreringsenheden er udformet til registrering

af mindst et billede (102), som afbilder afføring fra et eller flere af dyrene (132), idet analysesoftwaren er udformet til at gennemføre en fremgangsmåde omfattende:

- lagring af det mindst ene registrerede billede (102) i databasen;
- 5 • indlæsning (502) af det mindst ene registrerede billede (102) i analysesoftwaren (108);
- gennemførelse (504) af en analyse af det mindst ene billede;
- udlæsning (506) af en anbefalet handling, som er egnet til at bevare eller forbedre dyrenes aktuelle fysiologiske tilstand, med
- 10 analysesoftwaren, idet den anbefalede handling afhænger af et resultat af analysen af det mindst ene billede; og/eller
- udlæsning (508) af en forudsagt manifestation af en ydelsesindikator for et eller flere af dyrene med analysesoftwaren, idet ydelsesindikatoren er en fysiologisk parameter, et
- 15 sygdomssymptom eller en sygdom, idet den forudsagte manifestation afhænger af et resultat af analysen af det mindst ene billede;
- eventuelt en eller flere sensorer (134), der er anbragt i en dyrestald (130) eller på et område, hvor dyrene holdes, idet sensorerne er udformet
- 20 til at registrere måleværdier og transmittere dem til analysesoftwaren.

21. System ifølge krav 20, hvori computersystemet er et fordelt computersystem bestående af en server-computer (310) og mindst en client-computer (300), idet analysesoftwaren er udformet som fordelt client-server-softwareapplikation med

25 en server-applikation (302) på server-computersystemet og en client-applikation (304) på client-computeren eller hver af client-computerne, endvidere omfattende:

- mindst et slagteri-computersystem (710), der drives af et slagteri, og som er forbundet med en slagteri-billedregistreringsenhed (716), idet
- 30 slagteri-computersystemet indbefatter en feedback-applikation (726), idet slagteri-billedregistreringsenheden er udformet til registrering af billeder (728), som illustrerer mave-tarmkanalen fra et eller flere af dyrene (132) efter deres slagtning,

idet feedback-applikationen er udformet til:

- transmission over et netværk (136) af de registrerede mave-tarmkanal-billeder til server-applikationen til lagring af mave-tarmkanal-billederne i databasen;

idet server-applikationen er udformet til at gennemføre en fremgangsmåde

5 omfattende:

- modtagelse af mindst et digitalt billede (102) af afføring fra et eller flere af dyrene fra den mindst ene client-applikation og lagring af dette mindst ene billede i databasen;
- modtagelse af mindst en målt eller af en bruger over et GUI til client-applikationen eller feedback-applikationen indlæst manifestation af en ydelsesindikator for de dyr, hvis afføring er afbildet i det mindst ene modtagne billede, fra client-applikationen eller fra feedback-applikationen, idet manifestationen af ydelsesindikatoren især er billeder af mave-tarmkanalen efter dyrenes slagtning;
- træning af en machine-learning-algoritme til automatisk tilvejebringelse af en forbedret version af analysesoftwaren, idet træningen omfatter en analyse af de modtagne kombinationer af digitalt billede af afføringen og målt manifestation af ydelsesindikatoren.

20 **22.** Mobil robot (600) omfattende:

- en motorenhed, der er udformet til autonom eller semiautonom bevægelse af robotten inde i en dyrestald eller på et område, hvor dyrene holdes, idet robotten indbefatter en billedregistreringsenhed (140), der er udformet og rettet således, at den registrerer mindst et billede af afføringen fra et eller flere af dyrene;
- et netværksinterface (208);
- en billedregistreringsenhed (140);
- en eller flere processorer; og
- et lagermedium (602), på hvilket der er lagret en robotsoftware,

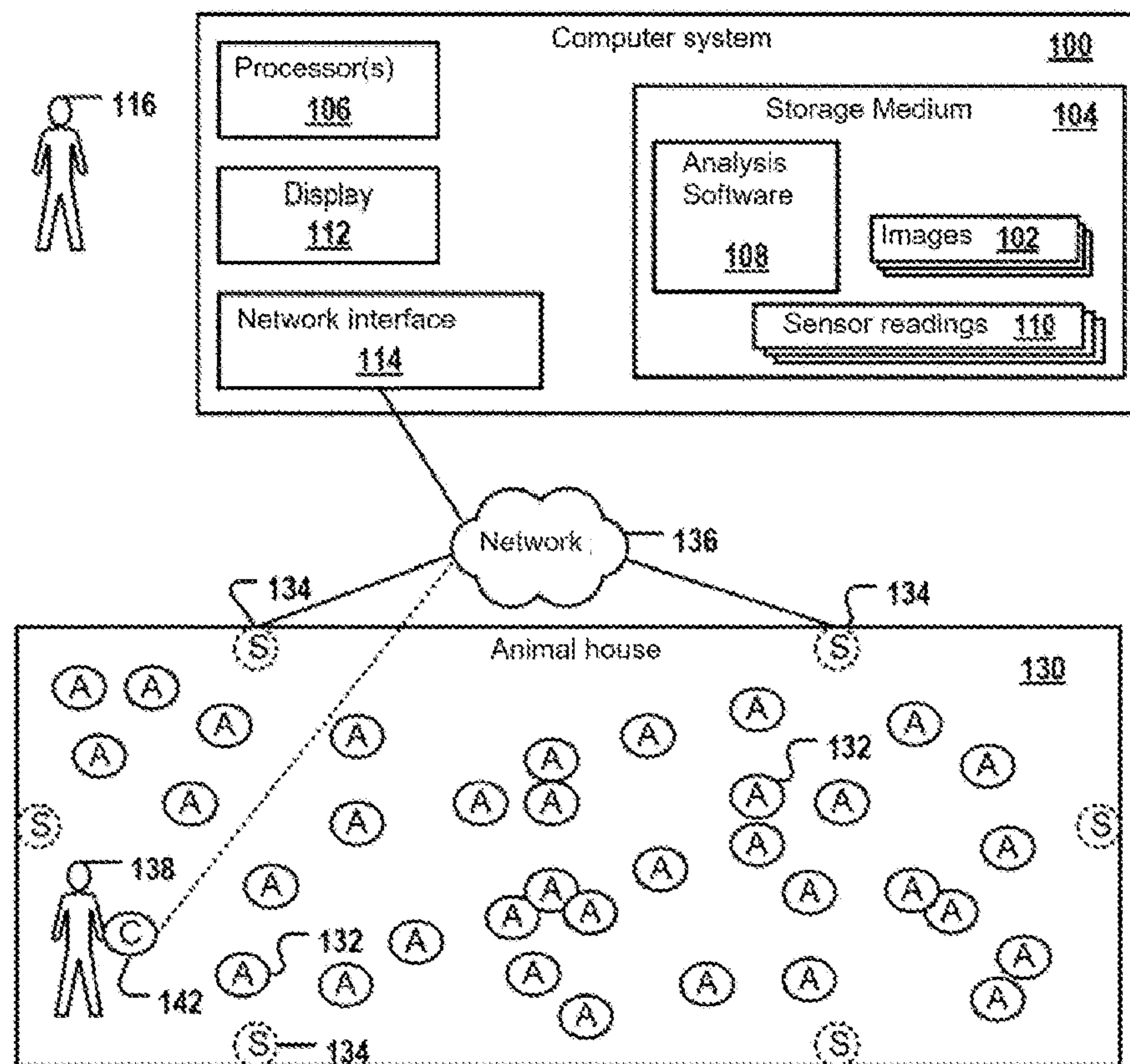
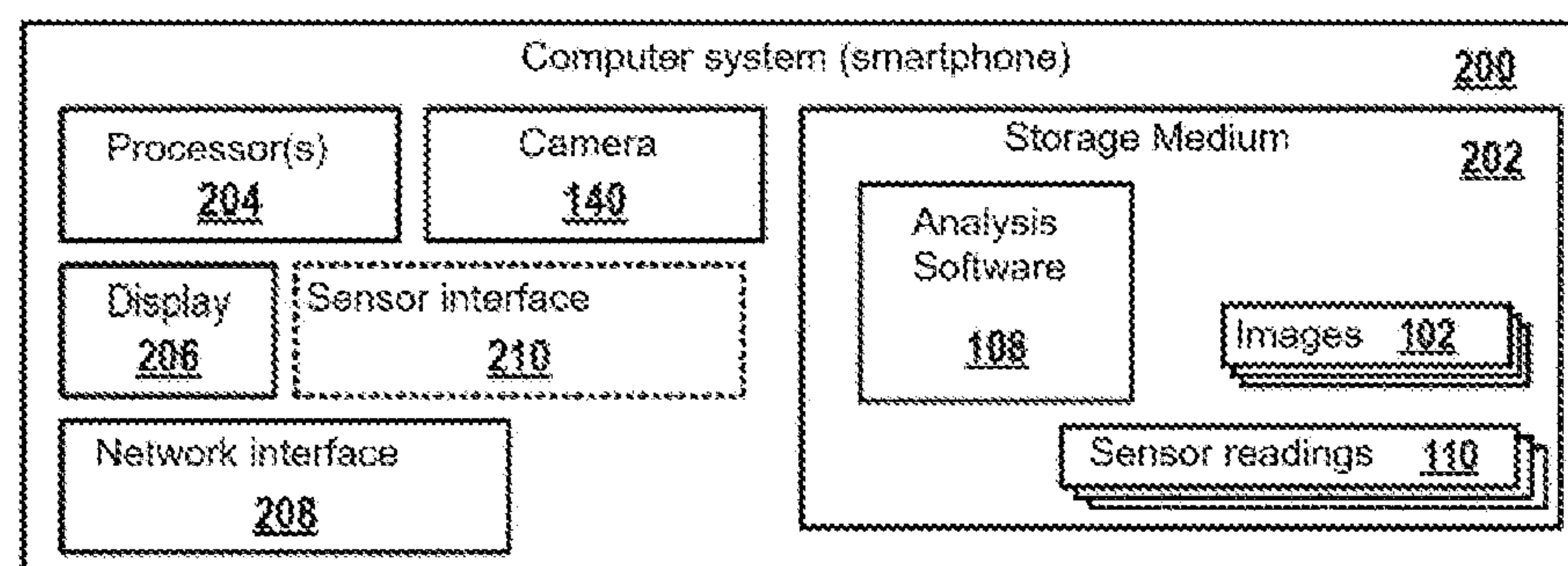
30 idet robotsoftwaren er udformet til alene eller samvirkende med en over et netværk forbunden server at udføre en fremgangsmåde omfattende:

- registrering af mindst et billede (102) med billedregistreringsenheden, idet det mindst ene billede er et digitalt billede, som afbilder afføring fra et eller flere af dyrene;
- indlæsning (502) af det digitale billede (102) i robotsoftwaren (108);

- gennemførelse af en analyse (504) af det modtagne billede med robotsoftwaren (108);
 - udlæsning (506) af en anbefalet handling, som er egnet til at bevare eller forbedre dyrenes aktuelle fysiologiske tilstand, med robotsoftwaren, idet den anbefalede handling afhænger af et resultat af analysen af det mindst ene billede; og/eller
 - udlæsning (508) af en forudsagt manifestation af en ydelsesindikator for et eller flere af dyrene med robotsoftwaren, idet ydelsesindikatoren er en fysiologisk parameter, et sygdomssymptom eller en sygdom, idet den forudsagte manifestation afhænger af et resultat af analysen af det mindst ene billede;
- idet udlæsningen af den anbefalede handling og/eller af den forudsagte manifestation til en bruger (116, 138) foregår over en visningsindretning på den mobile robot eller over et med robotten over et netværk forbundet databehandlingsapparat.

23. Kombination af:

- et fodertilsætningsstof med et indikatorstof, idet indikatorstoffet er et stof, der fremkalder en farvning i dyrenes afføring, som afhænger af fysiologiske betingelser i dyrenes stofskifte; og
- et system ifølge krav 20, hvor analysesoftwaren er udformet til på grundlag af optiske kendetegn ved afføringen fra dyr, som har optaget indikatorstoffet med foderet eller drikkevandet inden optagelsen af det mindst ene billede, at forudsige manifestationen af ydelsesindikatoren og/eller at beregne den anbefalede handling.

**Fig. 1****Fig. 2**

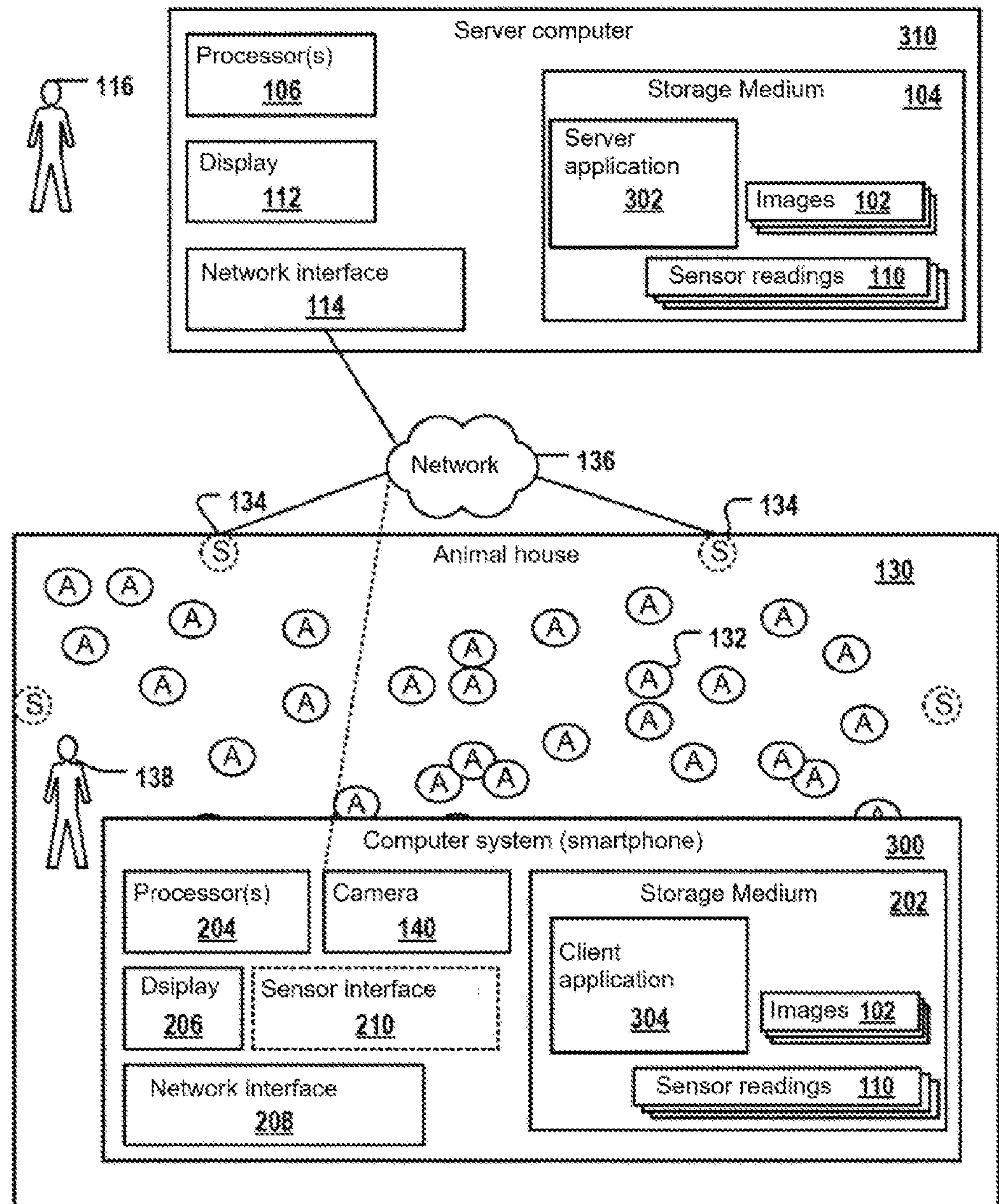


Fig. 3

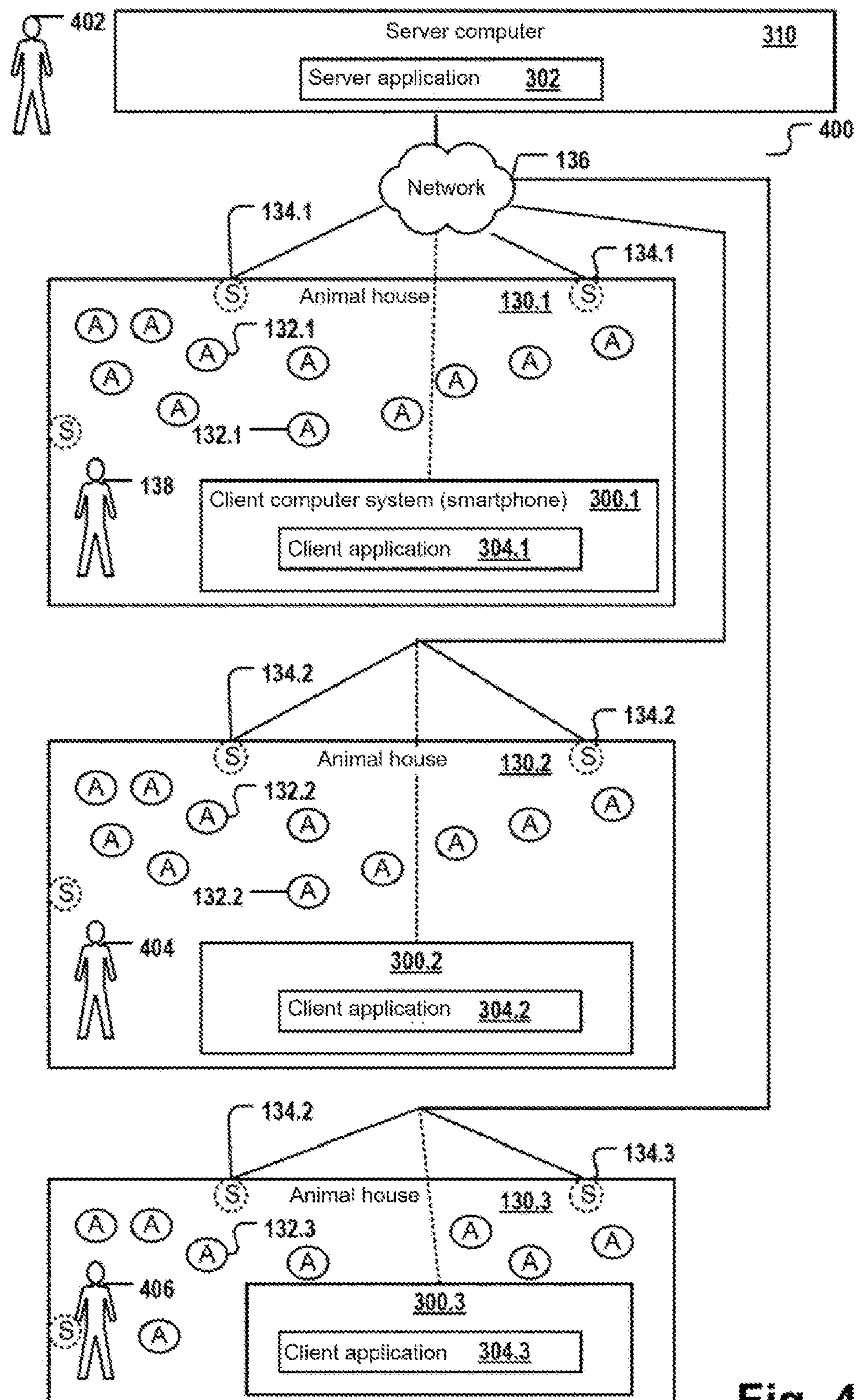


Fig. 4

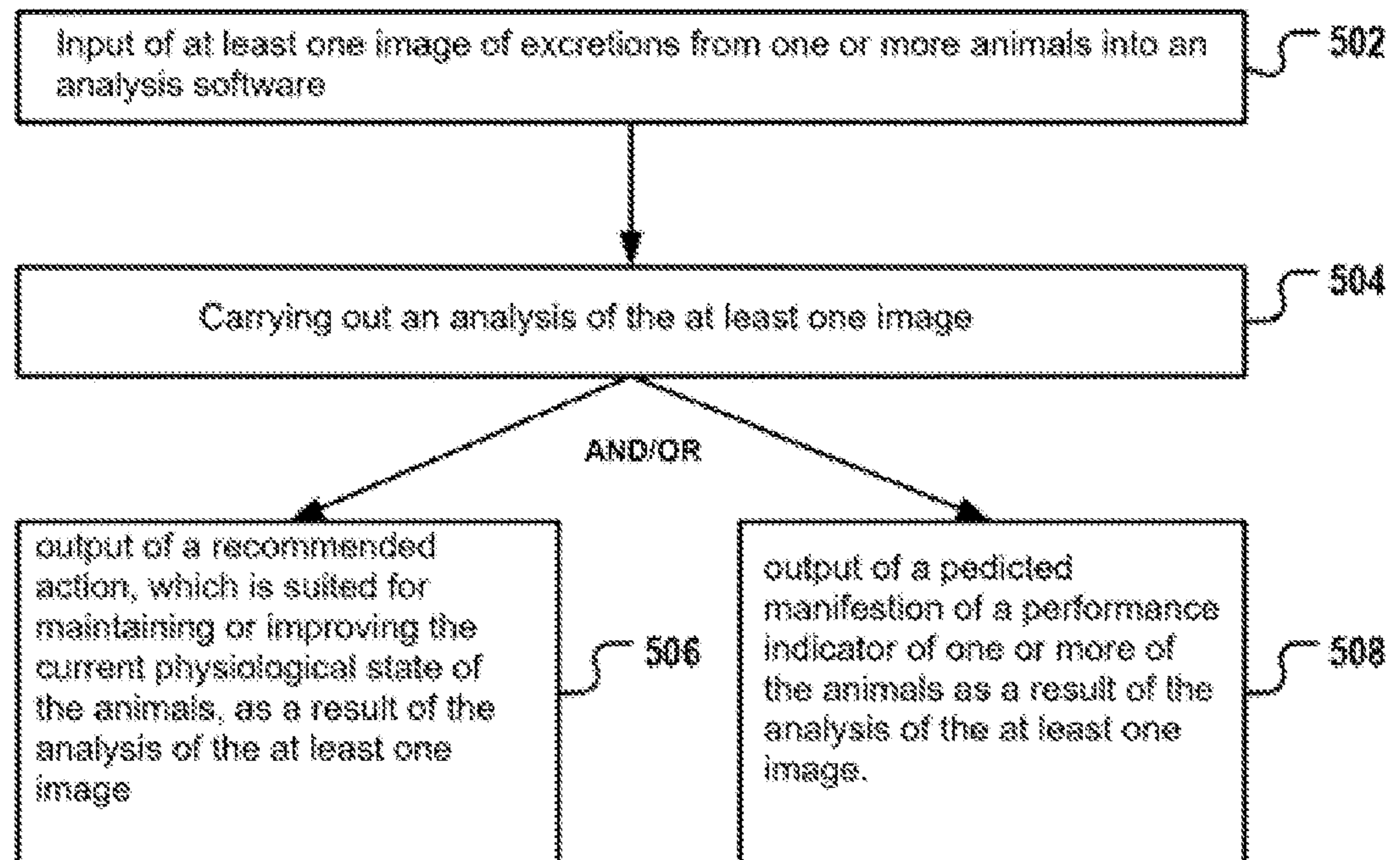


Fig. 5

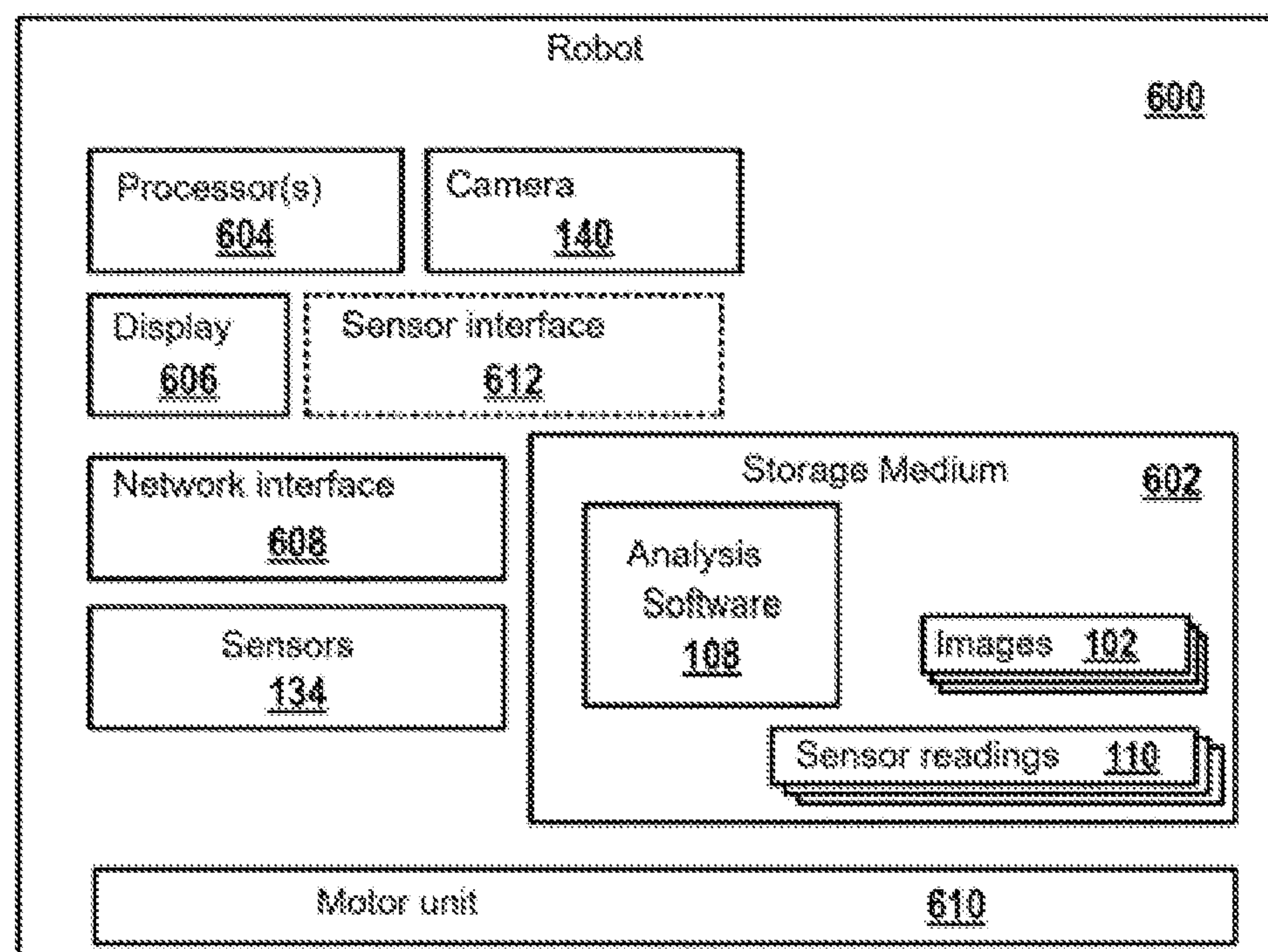


Fig. 6

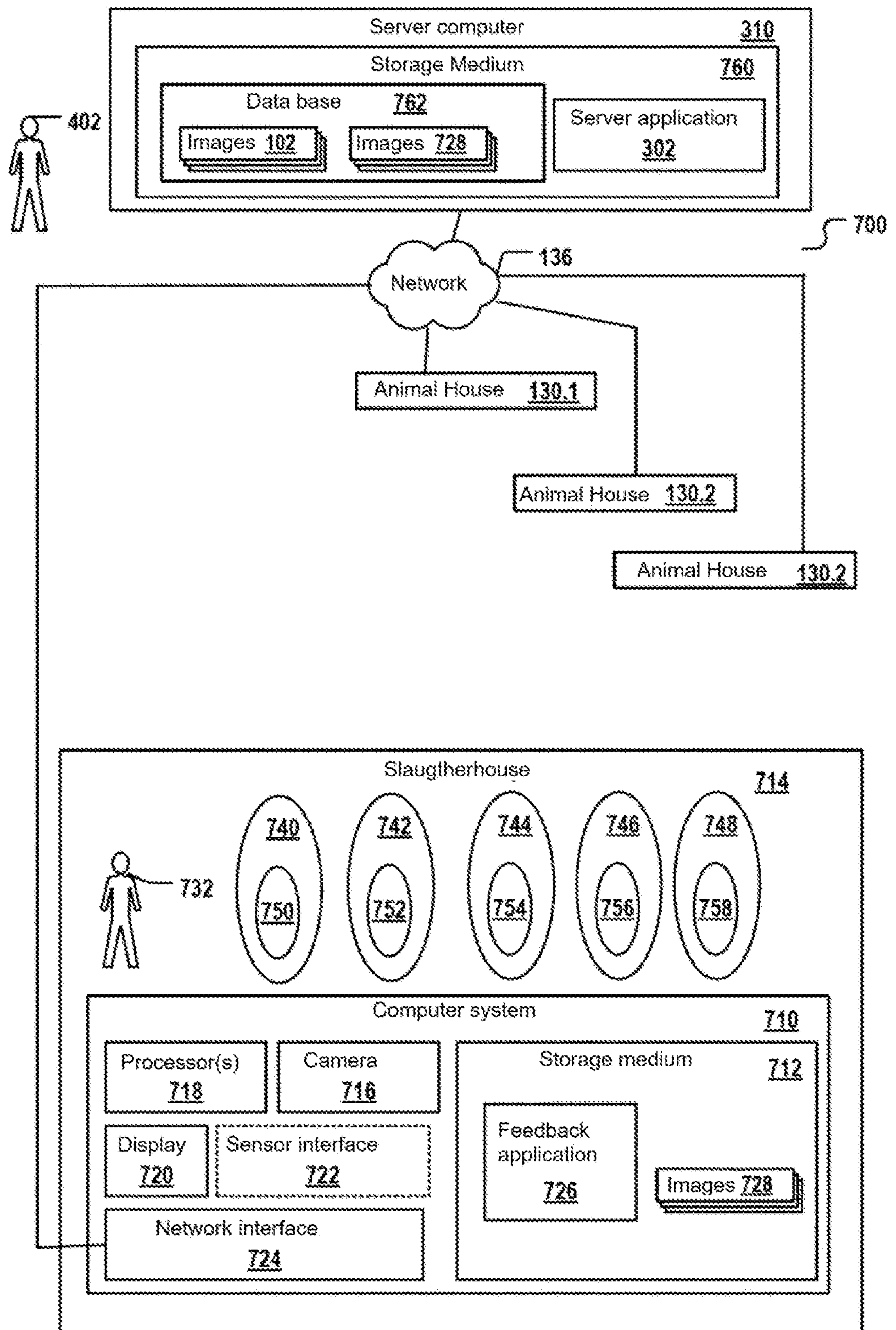


Fig. 7

Turkey, chlostridien

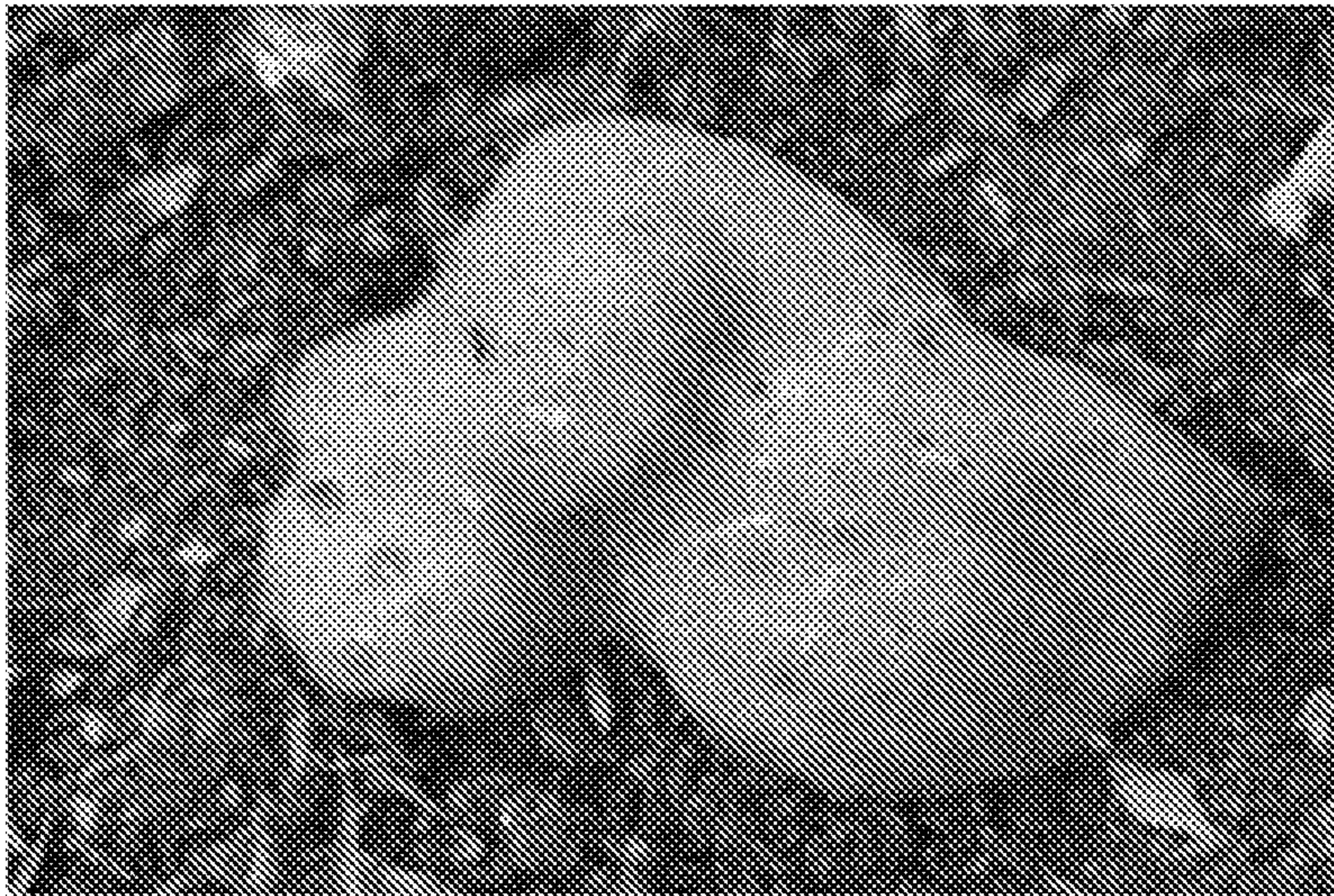


Fig. 8A



Fig. 8B



Fig. 8C

Turkey colisepsis

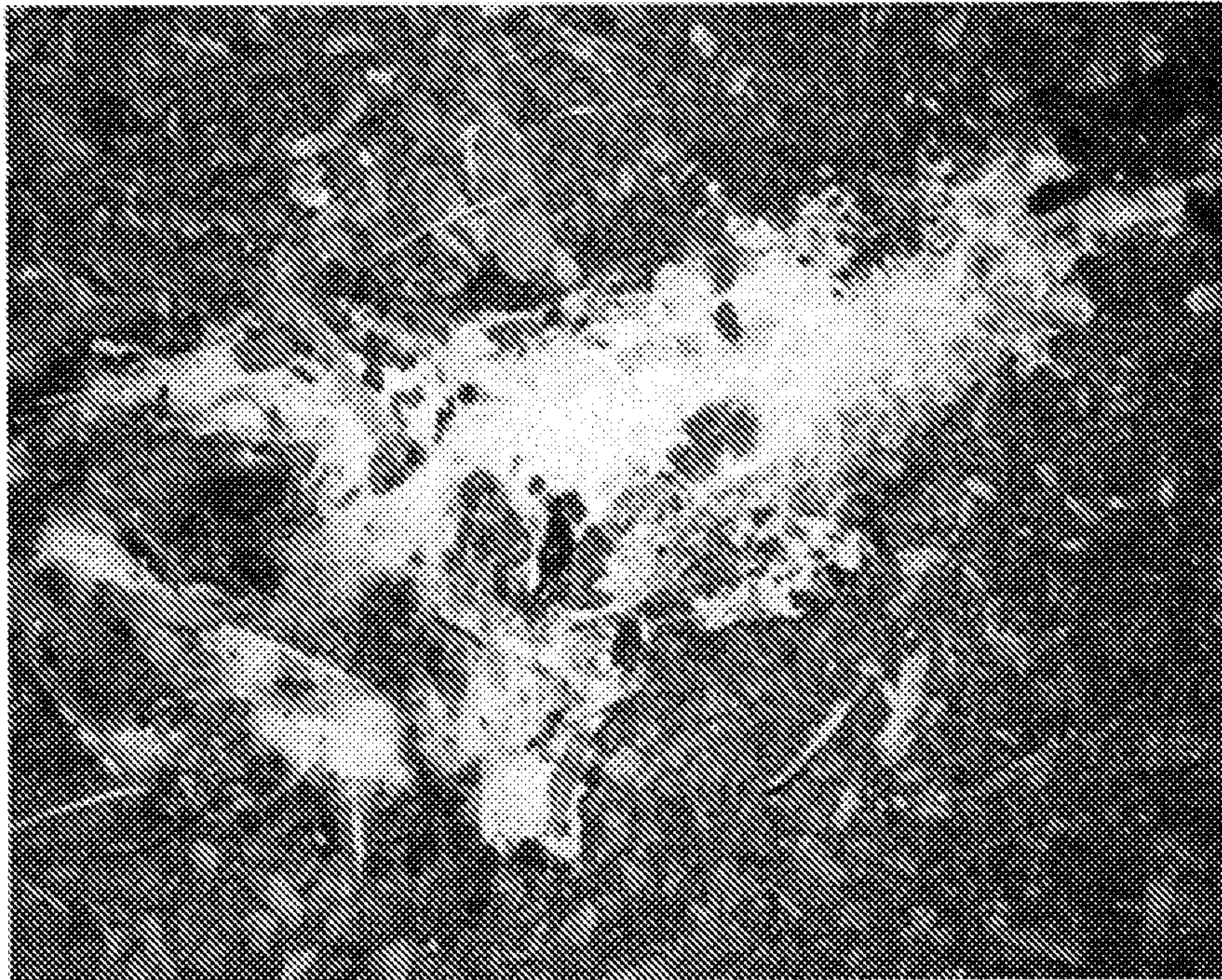


Fig. 9A

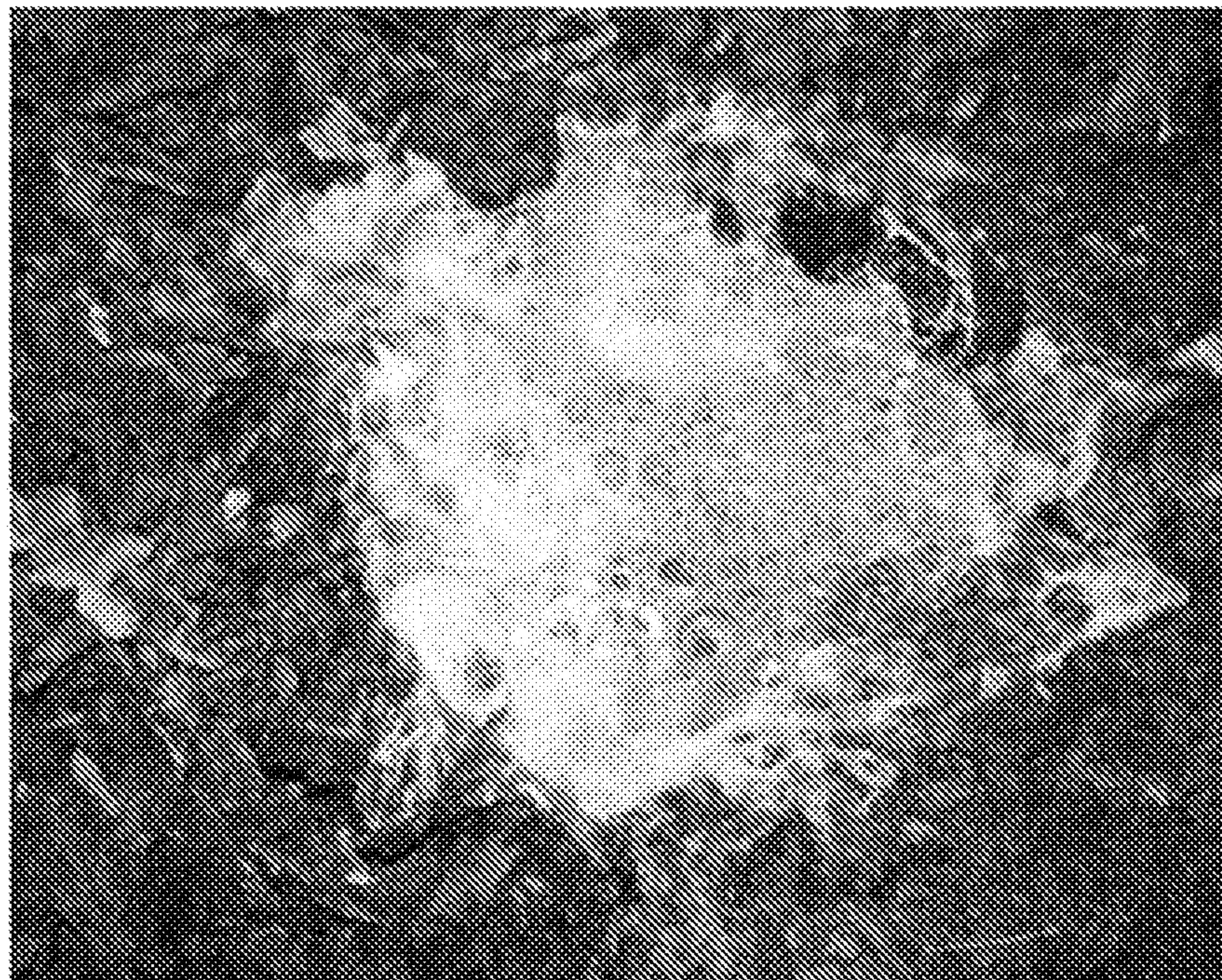


Fig. 9B

Turkey colicapsis

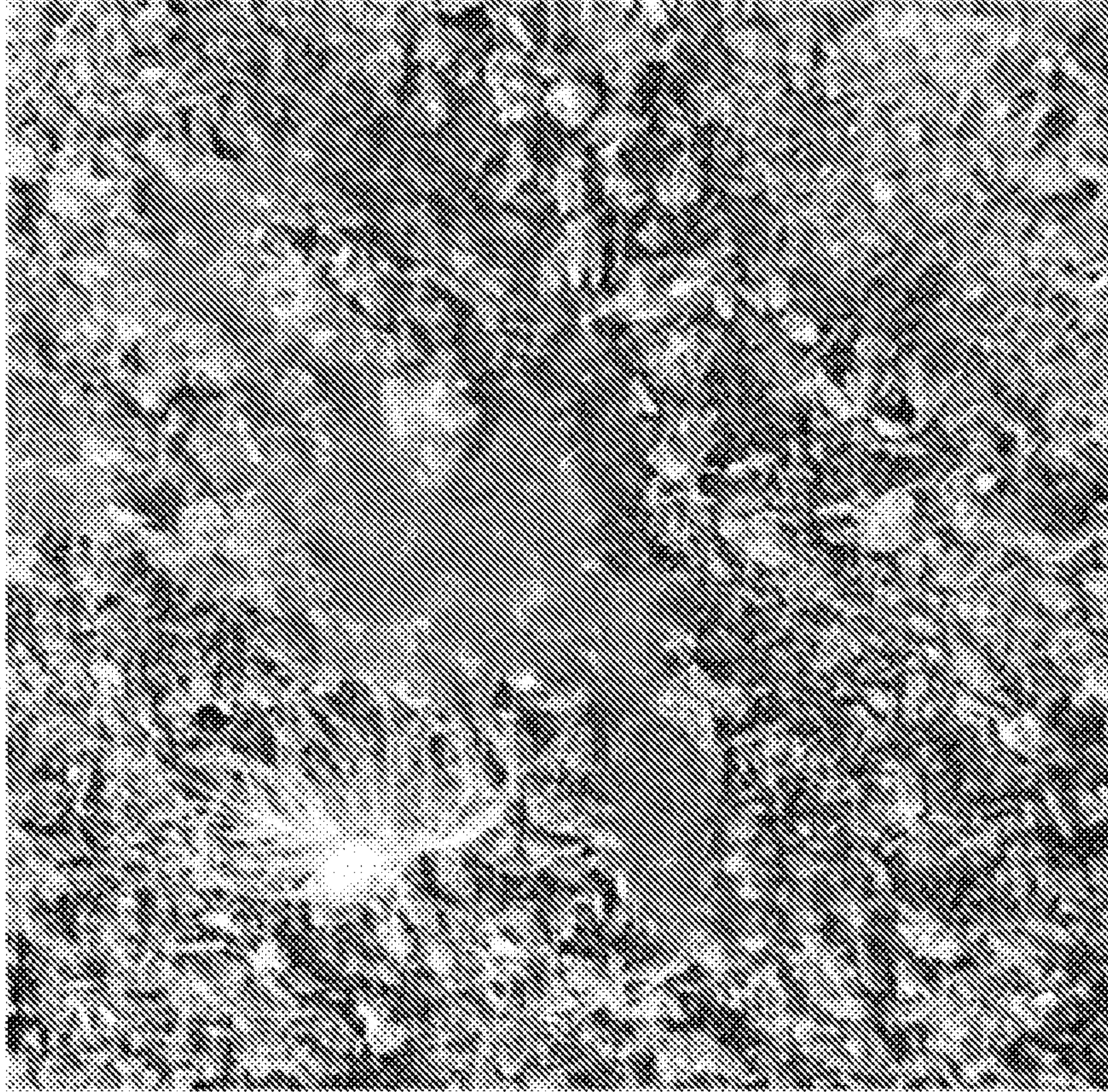


Fig. 10

WG: Broiler, clostridi + cocci



Fig. 11

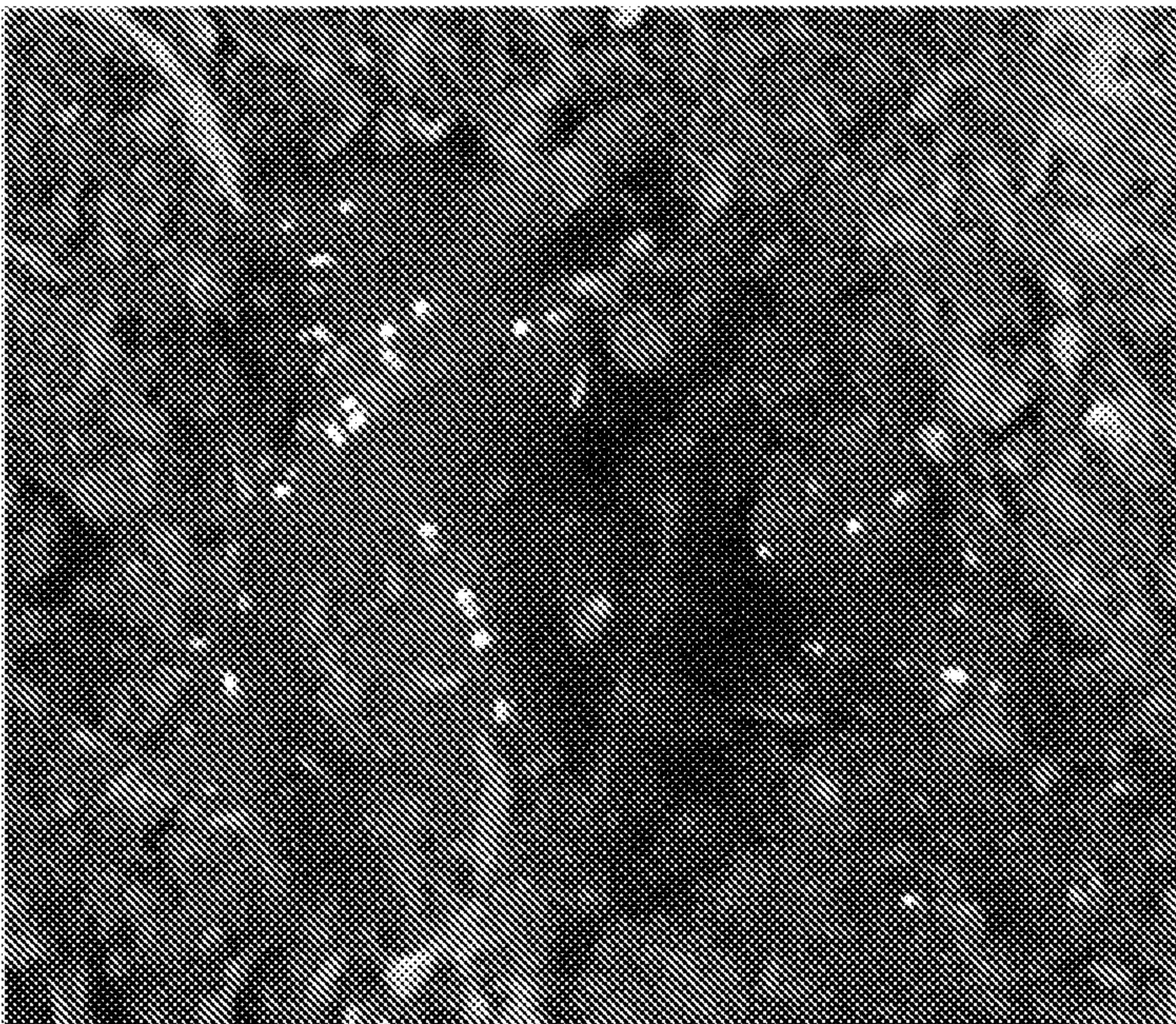


Fig. 12

WG: Broiler, clostridi