BRIEF SUMMARY

[0006] Various examples are described including systems, methods, and devices relating to locating, classifying, and counting insects using predictive models.

[0007] A system of one or more computers can be configured to perform particular operations or actions by virtue of having software, firmware, hardware, or a combination of them installed on the system that in operation causes or cause the system to perform the actions. One or more computer programs can be configured to perform particular operations or actions by virtue of including instructions that, when executed by data processing apparatus, cause the apparatus to perform the actions. One general aspect includes a computer-implemented method, including: accessing an image depicting a plurality of insects on a surface. The computer-implemented method also includes dividing the image into a plurality of image patches; defining, for each image patch, a central region and a context region, the context region surrounding the central region; providing at least some of the image patches with the corresponding defined central regions and the corresponding defined context regions to a predictive model; determining, using the predictive model, locations of individual insects of the plurality of insects in the image based on the provided central regions and context regions, wherein determining the locations of the individual insects in the image comprises: determining a first location of a first insect based at least in part on a particular central region; and determining a second location of a second insect based at least in part on a particular context region that includes a portion of the second insect . The computer-implemented method also includes classifying, using the predictive model and based on the provided central regions and context regions, the individual insects into at least one category based at least in part on an insect parameter. The computer-implemented method also includes outputting insect information from the predictive model based at least in part on the locations of the individual insects and the at least one category. As disclosed, the computer-implemented method also includes dividing the image into a plurality of image patches. Other embodiments of this aspect include corresponding computer systems, apparatus, and computer programs recorded on one or more computer storage devices, each configured to perform the actions of the methods.

[0008] One general aspect includes a system, including: an imaging device configured to capture images of insects supported by a surface; a computing device in communication with the imaging device, and configured to at least cause the imaging device to capture an image of the surface, the image depicting a plurality of insects. The computing device is also configured to divide the image into a plurality of image patches; define, for each image patch, a central region and a context region, the context region surrounding the central region; provide at least some of the image patches with the corresponding defined central regions and the corresponding defined context regions to a predictive model; determine, using the predictive model, locations of individual insects of the plurality of insects in the image based on the provided central regions and context regions, wherein determining the locations of the individual insects in the image comprises: determining a first location of a first insect based at least in part on a particular central region; and determining a second location of a second insect based at least in part on a particular context region that includes a portion of the second insect. The computing device is also configured to classify, using the predictive model and based on the provided central regions and context regions, the individual insects into at least one category based at least in part on an insect characteristic. The computing device is also configured to determine whether additional images should be captured based on a confidence value; and output insect information from the predictive model based at least in part on the locations of the individual insects and the at least one category. Other embodiments of this aspect include corresponding computer systems, apparatus, and computer programs recorded on one or more computer storage devices, each configured to perform the actions of the methods.

[0009] One general aspect includes one or more non-transitory computer-readable medium including computer-executable instructions that, when executed by one or more computer systems, cause the computer systems to perform operations including: accessing an image depicting a plurality of insects on a surface; dividing the image into a plurality of image patches; defining, for each image patch, a central region and a context region, the context region surrounding the central region; providing at least some of the image patches with the corresponding defined central regions and the corresponding defined context regions to a predictive model; determining, using the predictive model, locations of individual insects of the plurality of insects in the image based on the provided central regions and context regions, wherein determining the locations of the individual insects in the image comprises: determining a first location of a first insect based at least in part on a particular central region; and determining a second location of a second insect based at least in part on a particular context region that includes a portion of the second insect; classifying, using the predictive model and based on the provided central regions and context regions, the individual insects into at least one category based at least in part on a mosquito characteristic; and outputting insect information from the predictive model based at least in part on the locations of the individual insects and the at least one category. As disclosed, the one or more non-transitory computer-readable medium also includes dividing the image into a plurality of image patches. Other embodiments of this aspect include corresponding computer systems, apparatus, and computer programs recorded on one or more computer storage devices, each configured to perform the actions of the methods.

[0010] One general aspect includes a computer-implemented method, including: accessing image data representing first and second mosquitoes on a surface. The computer-implemented method also includes dividing the image into a plurality of image patches; defining, for each image patch, a central region and a context region, the context region surrounding the central region; evaluating, using a predictive model, a first image patch of the plurality of image patches by at least: (i) locating the at least one mosquito represented in the central region of the first image

patch (ii) locating the second mosquito, a portion of which is represented in the context region of the first image patch; and (iii) classifying the first and second mosquitoes into at least one category based at least in part on an insect parameter and the central region and the context region. The computer-implemented method also includes outputting insect information from the predictive model based at least in part on locating the first and second mosquitoes and classifying the first and second mosquitoes. As disclosed, the computer-implemented method also includes dividing the image data into a plurality of image portions. Other embodiments of this aspect include corresponding computer systems, apparatus, and computer programs recorded on one or more computer storage devices, each configured to perform the actions of the methods.

WHAT IS CLAIMED IS:

1. A computer-implemented method, comprising:

accessing an image depicting a plurality of insects on a surface;

dividing the image into a plurality of image patches;

defining, for each image patch, a central region and a context region, the context region surrounding the central region;

providing at least some of the image patches with the corresponding defined central regions and the corresponding defined context regions to a predictive model;

determining, using the predictive model, locations of individual insects of the plurality of insects in the image based on the provided central regions and context regions, wherein determining the locations of the individual insects in the image comprises:

determining a first location of a first insect based at least in part on a particular central region; and

determining a second location of a second insect based at least in part on a particular context region that includes a portion of the second insect;

classifying, using the predictive model and based on the provided central regions and context regions, the individual insects into at least one category based at least in part on an insect parameter; and

outputting insect information from the predictive model based at least in part on the locations of the individual insects and the at least one category.

2. The computer-implemented method of claim 1, further comprising training the predictive model based at least in part on annotated image data patches that comprise annotations identifying and classifying insects present in the annotated image data patches.

3. The computer-implemented method of claim 2, wherein each annotation of the annotations comprises (i) an identification of a head of an insect of the insects, (ii) an identification of a distal end of an abdomen of the insect, and (iii) an axis extending between the identification of the head and the identification of the distal end of the abdomen.

4. The computer-implemented method of claim 2, wherein training the predictive model comprises:

randomly selecting individual portions of a training image;

providing the individual portions for presentation at a user interface of a user device;

receiving, via the user interface, user input comprising the annotations with respect to the individual portions; and

associating the annotations with the individual portions to create the annotated image data patches.

5. The computer-implemented method of claim 1, wherein the image is divided into a plurality of image patches, each being sized to depict an adult insect.

6. The computer-implemented method of claim 1, wherein at least a portion of the plurality of insects are in a larva stage, a pupa stage, or an adult stage.

7. The computer-implemented method of claim 1, wherein at least a first portion of the plurality of insects are male and a second portion are female.

8. The computer-implemented method of claim 1, further comprising providing a user interface for presentation at a computing device based at least in part on the insect information, the user interface comprising user interface elements corresponding to the individual insects.

9. The computer-implemented method of claim 8, wherein a formatting of the user interface elements corresponds to the at least one category.

10. The computer-implemented method of claim 1, further comprising classifying, using the predictive model, the individual insects into at least one other category based at least in part on the insect parameter and probabilities that the individual insects belong to the at least one category.

11. The computer-implemented method of claim 1, further comprising classifying, using the predictive model, the individual insects into at least one other category based at least in part on a different insect parameter and probabilities that the individual insects belong to the at least one other category.

12. The computer-implemented method of claim 1, wherein the insect parameter comprises a sex parameter, a species parameter, a health parameter, a size parameter, a count parameter, or a life-stage parameter.

13. The computer-implemented method of claim 1, wherein the surface comprises a petri dish configured to retain the plurality of insects in an inactive state or an insect pathway configured to retain the plurality of insects in an active state.

14. The computer-implemented method of claim 1, further comprising counting, using the predictive model, the individual insects in the image.

15. A system, comprising:

an imaging device configured to capture images of insects supported by a surface; and

a computing device in communication with the imaging device, and configured to at least:

cause the imaging device to capture an image of the surface, the image depicting a plurality of insects;

divide the image into a plurality of image patches;

define, for each image patch, a central region and a context region, the context region surrounding the central region;

provide at least some of the image patches with the corresponding defined central regions and the corresponding defined context regions to a predictive model;

determine, using the predictive model, locations of individual insects of the plurality of insects in the image based on the provided central regions and context regions, wherein determining the locations of the individual insects in the image comprises:

determining a first location of a first insect based at least in part on a particular central region; and

determining a second location of a second insect based at least in part on a particular context region that includes a portion of the second insect;

classify, using the predictive model and based on the provided central regions and context regions, the individual insects into at least one category based at least in part on an insect characteristic;

determine whether additional images should be captured based on a confidence value; and

output insect information from the predictive model based at least in part on the locations of the individual insects and the at least one category.

16. The system of claim 15, wherein:

the system further comprises a display device in communication with the computing device; and

the computing device is further configured to provide a user interface on the display device based at least in part on the insect information, the user interface comprising user interface elements corresponding to the individual insects.

17. The system of claim 16, wherein the user interface elements discriminate between first insects classified into the at least one category and second insects not classified into the at least one category.

18. The system of claim 15, wherein the insect information comprises:

location information identifying the locations with respect to the surface; and

classification information identifying the at least one category.

19. The system of claim 15, wherein outputting the insect information comprises outputting first insect information that identifies a sex of an insect in the at least one category and outputting second insect information that identifies a location of the insect in the image.

20. The system of claim 15, wherein:

the insect information comprises instructions for performing an action with respect to at least one insect belonging to the at least one category; and

the action comprises (i) a removal action that, when performed, causes removal of the at least one insect from the surface or (ii) a sterilization action that, when performed, sterilizes the at least one insect.

21. The system of claim 19, wherein the system further comprises a robotic manipulator in communication with the computing device, the robotic manipulator configured to execute the instructions to perform the action.

22. One or more non-transitory computer-readable medium comprising computer-executable instructions that, when executed by one or more computer systems, cause the computer systems to perform operations comprising:

accessing an image depicting a plurality of insects on a surface;

dividing the image into a plurality of image patches;

defining, for each image patch, a central region and a context region, the context region surrounding the central region;

providing at least some of the image patches with the corresponding defined central regions and the corresponding defined context regions to a predictive model;

determining, using the predictive model, locations of individual insects of the plurality of insects in the image based on the provided central regions and context regions, wherein determining the locations of the individual insects in the image comprises:

determining a first location of a first insect based at least in part on a particular central region; and

determining a second location of a second insect based at least in part on a particular context region that includes a portion of the second insect;

classifying, using the predictive model and based on the provided central regions and context regions, the individual insects into at least one category based at least in part on a mosquito characteristic; and

outputting insect information from the predictive model based at least in part on the locations of the individual insects and the at least one category.

23. A computer-implemented method, comprising:

accessing image data representing first and second mosquitoes on a surface;

dividing the image into a plurality of image patches;

defining, for each image patch, a central region and a context region, the context region surrounding the central region;

evaluating, using a predictive model, a first image patch of the plurality of image patches by at least:

(i) locating the at least one mosquito represented in the central region of the first image patch;

(ii) locating the second mosquito, a portion of which is represented in the context region of the first image patch; and

(iii) classifying the first and second mosquitoes into at least one category based at least in part on an insect parameter and the central region and the context region; and

outputting insect information from the predictive model based at least in part on locating the first and second mosquitoes and classifying the first and second mosquitoes.

24. The computer-implemented method of claim 23, wherein the predictive model comprises a neural network.

25. The computer-implemented method of claim 23, further comprising, prior to evaluating the first image portion, randomly selecting the first image portion from the plurality of image portions.

26. The computer-implemented method of claim 23, wherein the insect information comprises location information that identifies a location of the at least one mosquito and classification information that identifies the at least one category to which the at least one mosquito was classified.

27. The computer-implemented method of claim 23, wherein a dimension of the central region corresponds to a length dimension of an adult mosquito.