Design of an Image Generation Truth Model for Testing Attitude Determination Algorithms for a Star Tracker

Master of Science in Aerospace Engineering

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San José State
UNIVERSITY

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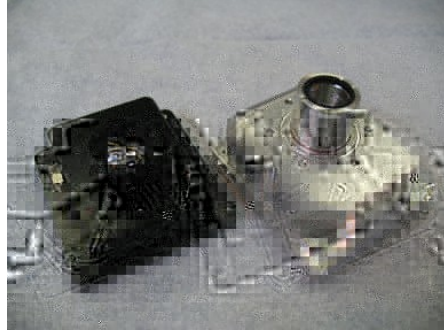
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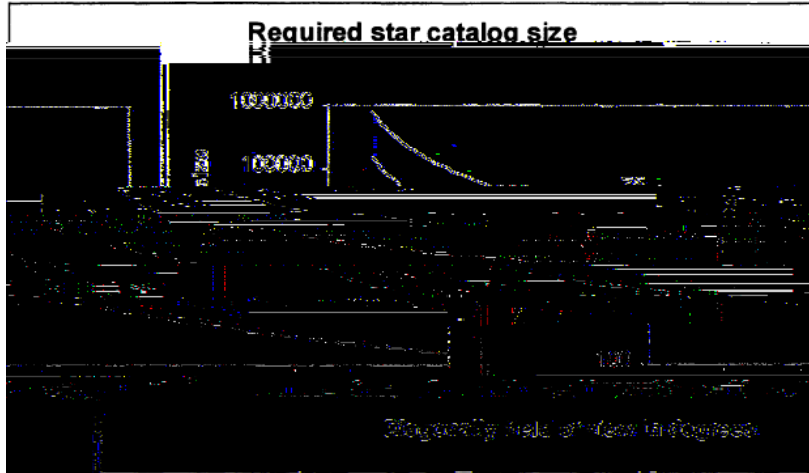
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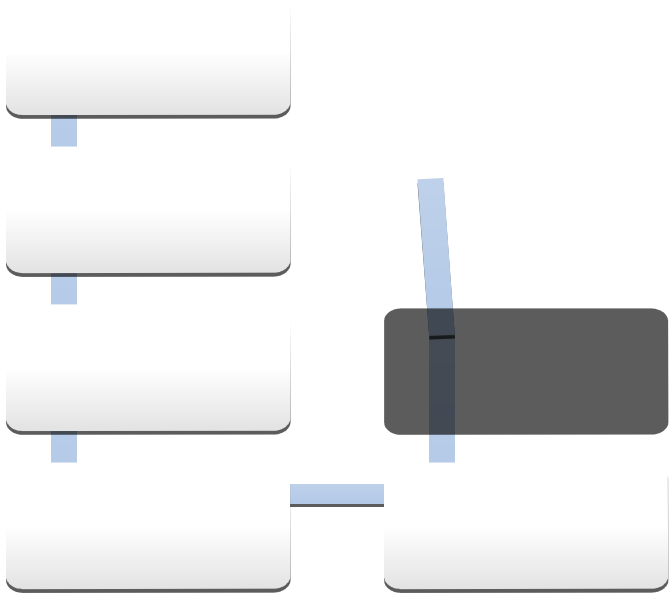
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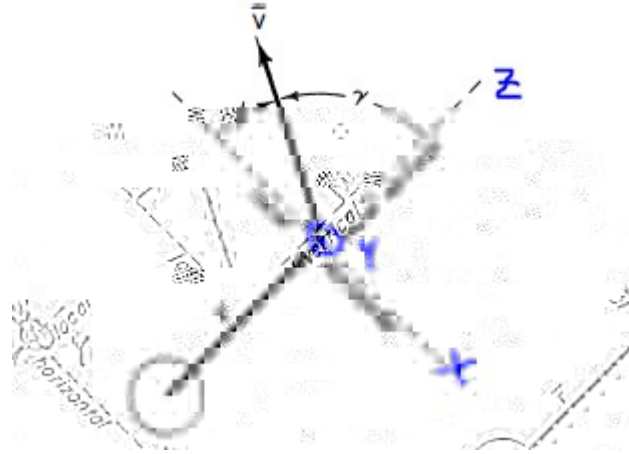
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Table 5-4: Image Generation Results

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Figure 10-14: Star Tracker +ode @lock iagra!

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Figure 10-1, : Tria″gular Feature a#ter Star ?atc%i″g

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    p otons  &  p otonH  –   nt >(             % *p otons+
    s  $starH  –%(

    s n  &  $$$3 pi   cC3%!D$  a .  a!C9!  $e-p$$   c%!D$  a .  a!  7  s nN%%6'%%%%#(

%     i  re$'%
%    p ot$  a .  a5s n5#.#%
%    tit e$#  n H  – 6 ,e erence  tar#%
%     e en $#@  a  &  63 !;#%
%    – a.e $#R  a .  a *  +#%51 a.e $#*O D  C3+#%
%
%     i  re$3%
%    p ot$  a .  a5starH  –5#r#%
%    tit e$#  tar H  –#%
%     e en $*#@  a  &  #5n  3str$@  a %+%
%    – a.e $#R  a .  a *  +#%51 a.e $#*O D  C3+#%

%    OeinsLa"$  a .  a5starH  –5N%(

en
```
                    C!

C.'''': GenerateStar.m

```
% Description:   reates a star  i a e  i en  is a   a nit  e5 optiona 1
%               p ot  t e star in its o"n  i  re
```

```
% Description:  A ots a star  ie   in a i  re i en a J aternion
%  np ts:       J aternion
%   tp ts:        atri- "it  co nt  a  es5  tars str ct re "it
%              para eters inc   in : pi-e  coor inates5 @is a   a nit  e5
%              ca era coor inates5  D D n  .er
% Hns  se :      a era tar oor inates5 Ai-e  pace oor inates5 0enerate tar

   nction *   5 tars+ & 0enerate tarHie  $J%


specs & ca era specs$%(
 a  .ore &  a era tar oor inates$J5specs%(
star para eters & Ai-e  pace oor inates$J5specs5 a  .ore%(

 istI@ & star para eters!Ai-e  oor (
@ a  & star para eters! a (
.  & star para eters!. (
I & specs!I(
@ & specs!@(
EsiFe & specs!EsiFe(
    & Feros$@5I%(


 tars & *+(
 tars!I@ &  istI@(
 tars!coor  & star para eters! a era oor (
 tars! a  & @ a (
 tars! D D & star para eters! D D(

 or i & ': en t $ istI@%

     a  & @ a $i%(
    G@ & . $i%(
     &  istI@$i5'%(
     &  istI@$i53%(
    * nor 5  5  + & 0enerate tar$  a 5G@5specs5 5 %(

    coor  &   /':  /EsiFe(
    coor  &   /':  /EsiFe(
    p c   & coor     8 T  coor  )& '888(
    p c   & coor     8 T  coor  )& 3888(
     $ coor $p c  %5  coor $p c  %% &    $ coor $p c  %5   coor $p c  %% /
 nor $p c  5p c  %(
    % i  a star  a  s on t e e  e5 "i   on 1 p ot t e portion t at#s in H @
en


 i  re
i a esc$   %(
co or ap$ ra1%(


en
```

A--endi/ D: Algorithm Testing Matlab Files

D.": findCentroid.m

```
% Description:  Hin s t e centroi  o  a star  i en its  pper e t coor inate
%  np ts:      75  coor inates o   pper e t pi-e  on star  ie  5 ,e ion o
%                 nterest $,  %
%   tp ts:       entroi  in S6 ir5  entroi  in U6 ir

  nct ion * enS5 enU+ &  in  entroi $75 5,    %

s- &  en t $,     $:5'%%(
s1 &  en t $,     $'5:%%(
 1 & Feros$s-5s1%(
 - & Feros$s-5s1%(

restart  &  (
 or 77 & ':s-
     or    & ':s1
         1$775  % & ,    $775  % 7(
         -$775  % & ,    $775  %  (
          &    /  '(
     en
     7 & 7 /  '(
       & restart (
en

 enU & s  $ 1$:%%Ds  $,    $:%%(
 enS & s  $ -$:%%Ds  $,    $:%%(

en
```

D.$: starIdentification.m

```
% Description:    enti ies t e re ions o  interest $,  %  i en a star  ie
%               an ca c ates t e centroi s o  eac potentia star "in o"!
%               Oi  p ace re  crosses o er centroi s o  stars
%  np ts:         Qatri- o  star  ie
%   p ts:        ist o  entroi s5 ,  str ct re " ic  inc  es: star#s
%               centroi 5 star#s  a- co nt  a e5 star#s ,   "in o"
% Hns  se :      in  entroi

  nct ion *,  5 entroi s+ & star  enti ication$   %

specs & ca era specs$%(
EsiFe & specs!EsiFe(
 a-co nt  i star & 4(

 Q0 &     (
,   & *+(
star & '(
```

```
startne"L & 39(

 or ii & 39: en t $ Q0$:5'%%639(
    or LL & startne"L: en t $ Q0$'5:%%639(
    i & ii(
    L & LL(

    i   Q0$i5L%  &  a-co nt  i star
        co ntrL & '(
        co nt L & '(
        co nt i & '(
        co nt i & '(
        co nt3L & '(
        " i e  Q0$i5L/'%  &  Q0$i5L%
           L & L / '(
           co nt3L & co nt3L / '(
        en
        " i e  Q0$i/'5L%  &  Q0$i5L%
           i & i / '(
        en
        ne"i & i( ne"L & L( % ri  t
        " i e  Q0$ne"i5ne"L/'% V& 8
           ne"L & ne"L / '(
           co ntrL & co ntrL / '(
           i  ne"L && '
              .rea7
           en
        en
        ne"i & i( ne"L & L( %  e t
        " i e  Q0$ne"i5ne"L6'% V& 8
           ne"L & ne"L 6 '(
           co nt L & co nt L / '(
           i  ne"L && '
              .rea7
           en
        en
        ne"i & i( ne"L & L( %  p
        " i e  Q0$ne"i6'5ne"L% V& 8
           ne"i & ne"i 6 '(
           co nt i & co nt i / '(
           i  ne"i && '
              .rea7
           en
        en
        ne"i & i( ne"L & L( %  o"n
        " i e  Q0$ne"i/'5ne"L% V& 8
           ne"i & ne"i / '(
           co nt i & co nt i / '(
           i  ne"i && '
              .rea7
           en
        en

         tar, & *#star#5n  3str$star%+(
        ,  !$ tar,%!  &  Q0$i6co nt i:i/co nt i5L6co nt L:L/co ntrL%(
        ,  !$ tar,%!    $'5'% & i 6 co nt i(
```

```
            ,  !$ tar,%!     $'53% & L 6 co nt L(
            ,  ! a-co nts$star% &  a-$,  !$ tar,%! $:%%(
             Q0$i6co nt i:i/co nt i5L6co nt L:L/co ntrL% & 8(
            star & star / '(
            startne"L & co nt3L / co ntrL(
      en


      en
      startne"L & 39(
en


  entroi s & Feros$star6'53%(
  o   on
  or starn   & ':star6'
      tar, & *#star#5n  3str$starn  %+(
      ,     & ,  !$ tar,%! (
      7 & ,  !$ tar,%!    $'5'%(
       & ,  !$ tar,%!    $'53%(
      * enS5 enU+ &  in  entroi $75 5,    %(
       entroi s€
```

D.+: createStarCatalogDatabase.m

% Description: reates a ata.ase o   oca star para eters inc   in : D D

```matlab
% Description:   on erts a  ector in pi-e  space to t e ca era#s re erence
 ra e
% np ts:         a era specs5 Ai-e   pace  ector
%  tp ts:        orrespon in   ector in ca era space

  nction  a era pace@ector  & Ai-e 3 a era pace$specs5 A @ec%


 c & $specs!ID3%/'(
 c & $specs!@D3%/'(


 a era pace@ector & Feros$45'%(
@- @F & $ c 6 A @ec$'%% specs!ppDspecs! (
@1 @F & $ c 6 A @ec$3%% specs!ppDspecs! (
@F & sJrt$'6 @- @FC3 6 @1 @FC3%(
@- & @- @F @F(
@1 & @1 @F @F(
 a era pace@ector$'5'% & @-(
 a era pace@ector$35'% & @1(
 a era pace@ector$45'% & @F(


en
```

D.3: findAngles.m

```matlab
% Description:    a c ates t e sp erica an e an an   ar  istances
%                .et"een stars an o tp ts a tria o star  ectors in t e
%                ca era  ra e an  in pi-e  space!
% np ts:          ist o star  entroi s5 pi ot star n .er
%  tp ts:        NH & trian ar eat re inc es an  ar  istances ro t e
pi ot
%                star to 3 c osest stars an  t e sp erica an e .et"een t e

  nction *star@ectors5star@ectors Ai-e  5NH+ &  in >n es$ entroi s5pi ot%


specs & ca era specs$%(
Di   & Feros$ en t $ entroi s%/35 en t $ entroi s%%(
 or i & ': en t $ entroi s%
    star' & * entroi s$i5:% 6specs! Dspecs!pp+#(
    star'ca  & Ai-e 3 a era pace$specs5star'%(
     or L & ': en t $ entroi s%
        star- & * entroi s$L5:% 6specs! Dspecs!pp+#(
        star-ca  & Ai-e 3 a era pace$star-! )ß ð    )ß ð   < !◉
```

```
star@ectors Ai-e   & Feros$454%(
star@ectors Ai-e  $:5'% & * irstEei  .or 6specs! Dspecs!pp+#(
star@ectors Ai-e  $:53% & *pi otstar 6specs! Dspecs!pp+#(
star@ectors Ai-e  $:54% & *secon Eei  .or 6specs! Dspecs!pp+#(


star@ectors & Feros$454%(
 or i & ':4
star@ectors$:5i% & Ai-e 3 a era pace$star@ectors Ai-e  $:5i%%(
en


NH & Feros$'54%(
@' & star@ectors$:5'%(
@3 & star@ectors$:53%(  % pi ot
@4 & star@ectors$:54%(
 ' & star@ectors Ai-e  $:53% 6 star@ectors Ai-e  $:5'%(
 3 & star@ectors Ai-e  $:53% 6 star@ectors Ai-e  $:54%(
> & een!an& arDistances@35@e6tors & FeDm%'5 3%(
G &  in >n   arDistance$@35@4%(
  &  in >n   arDistance$ '5 3%(
NH$'5'% & > '<8Dpi(
NH$'53% & G '<8Dpi(
NH$'54% &   '<8Dpi(


en
```

D.6: findStarMatch.m

```
% Description:  Hin star atc  .et"een star cata o  an  t ose in t e H @
%  np ts:       tr ct re ca e  X tarsX " ic  inc   es  D D n  .ers o
%               stars  se  in  eneratin  i a es5 ist o   entroi s
%               i enti ie  in t e H @
```

```
P & *G/transpose$G% 6 trace$G% e1e$4% F( transpose$F% trace$G%+(
*ei @5 a . a+ & ei $P%(
J at & *ei @$=5=%( ei @$':45=%+(
t eta & $3 acos$ei @$=5=%%% '<8Dpi(


en
```

D."=: get 1uaternion , rror.m

```
% Description:   .tain t e error in esti ate  an  tr e J aternion!  o rt
%               para eter is t e sca ar
%  np ts:       ?sti ate  J aternion5 Nr e J aternion
%   tp ts:       >ttit  e error * e +


  nction attit  e?rror &  etB aternion?rror$J tr e5J est%


J tr e in  & *J tr e$'% J tr e$=% 6J tr e$4% J tr e$3%(!!!
    6J tr e$=% J tr e$'% J tr e$3% J tr e$4%(!!!
    J tr e$4% 6J tr e$3% J tr e$'% J tr e$=%(!!!
    6J tr e$3% 6J tr e$4% 6J tr e$=% J tr e$'%+(
J est & *6J est$3:=%( J est$'%+(

J err & J tr e in  J est(

attit  e?rror & 3 acos $J err$=%%(


en
```

D."": get ossFunction8alue.m

```
% Description: Hin s t e oss  nction a e so  tion to Oa .a#s pro. e
%  np ts:       @ectors o  stars in t e .o 1 an  inertia  re erence  ra es
%   tp ts:      Loss  nction a e5 M


  nction M &  etLossH nction@a  e$star@ectors5inertia @ectors%

 . & star@ectors(
 r & inertia @ectors(
ai & '( % "ei t
```

```
Gi & Feros$454%(
G & Feros$454%(
 or i & ':4
    Gi & ai  .$:5i% transpose$ r$:5i%%(
    G & G / Gi(
en


F & *G$354%6G$453%( G$45'%6G$'54%( G$'53%6G$35'%+(
P & *G/transpose$G% 6 trace$G% e1e$4% F( transpose$F% trace$G%+(
*ei @5 a . a+ & ei $P%( % ar est  a . a is  a . a$=5=%
 a . a a- &  a . a$=5=%(
 a . a8 & ai / ai / ai( %s   o  t e "ei  ts


M &  a . a86  a . a a-(%$transpose$J% P J%(


en
```

D."$: runMonteCarlo 1 Method.m

```
% Description:   , n co e to  enerate a star i a e an  o tp t t e
%               correspon in  J aternion! Loa s t e  tar ata o Data.ase an
%                a   ?  Q>N  i es5  enerates a star  ie   sin  a ran o
%               J aternion an  r ns t e star i enti ication a orit   to
%                in  a  atc .et"een t e stars in t e i a e an  t ose in t e
%               cata o ! N e co e "i   t en r n attit  e  eter ination  ia
%               t e B Qet o  an  o tp ttin  t e sa e J aternion  se  to
```

```
        , n & *#r n#5n  3str$i%+(
        Qonte ar oBQet o !J!$, n% & *J    0en J >ttDet+(
        Qonte ar oBQet o ! entroi s!$, n% &  entroi s(
        Qonte ar oBQet o !@ectors!$, n% & *star@ectors inertia @ectors+(
        Qonte ar oBQet o !attit  e?rror$i% & attit  e?rror(
    en

en
```

D."': calcMonteCarloAttitude‚rrror.m

```
% Description:   a c ate t e attit e error  ro  t e Qonte  ar o res  ts
% np ts:       Eone5 oa s at i e create   ro  r nQonte ar oBQet o !
%  tp ts:       > era e error in attit  e errors5 .ot  8 an  4 8  e rees

 oa $#Qonte ar oBQet o ! at#%
>ttit  e?rror & Qonte ar oBQet o !attit  e?rror(
FeroDe  & Feros$'8885'%(
t reesi-tDe  & Feros$'8885'%(
L & '( 7 & '(

 or i & ': en t $>ttit  e?rror%

   r n & >ttit  e?rror$i%(
   i  r n ) '
      FeroDe $L5'% & r n(
      L & L / '(
   en
   i  r n    '
       t reesi-tDe $75'% & r n(
       7 & 7 / '(
   en

en

 e eteFeros & FeroDe    8(
FeroDe  & FeroDe $ e eteFeros%(
 e eteFeros & t reesi-tDe    8(
t reesi-tDe  & t reesi-tDe $ e eteFeros%( %8 & 4 8  e rees in rotation

a  KeroDe  &  ean$FeroDe $:%%(
st KeroDe  & st $FeroDe $:%%(
a  N reesi-tDe  &  ean$t reesi-tDe $:%%(
st N reesi-tDe  & st $t reesi-tDe $:%%(
```

D."+: runScri‑t@StarTrackerforAttitudeDetermination.m

```
% r n cript  tarNrac7er or>ttit  eDeter ination!
```

>D