Writing an Icy Based Program

March 2006

Viewing This Tutorial

This coding example is an "animated" presentation that is best viewed using PowerPoint set to "Slide Show" mode.

Undefined variables are displayed in red; results are displayed in blue.

Introduction

First, let's go over the important steps in the process of writing a Icy-based program and putting it to work:

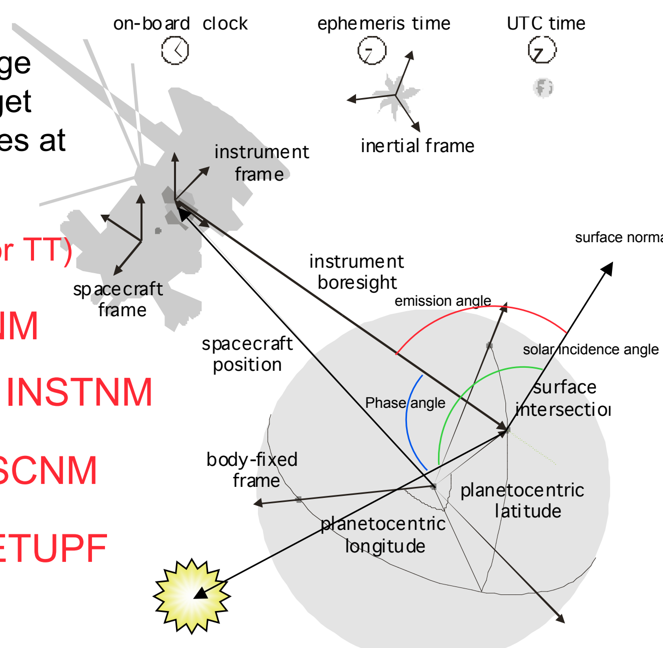
- **Understand the geometry problem.**
- **Identify the set of SPICE kernels that contain the data needed to perform the computation.**
- **Formulate an algorithm to compute the quantities of interest using SPICE.**
- **Write and compile the program.**
- **Get actual kernel files and verify that they contain the data needed to support the computation for the time(s) of interest.**
- **Run the program.**

To illustrate these steps, let's write a program that computes the apparent intersection of the boresight ray of a given CASSINI science instrument with the surface of a given Saturnian satellite. The program will compute:

- **Planetocentric and planetodetic (geodetic) latitudes and longitudes of the intercept point.**
- **Range from spacecraft to intercept point and from spacecraft to target center.**
- **Illumination angles (phase, solar incidence, and emission) at the intercept point.**

Observation geometry

We want the boresight intercept on the surface, range from s/c to intercept and target center, and illumination angles at the intercept point.



When? TIME (UTC, TDB or TT)

On what object? SATNM

For which instrument? INSTNM

For what spacecraft? SCNM

Using what model? SETUPF

Needed Data

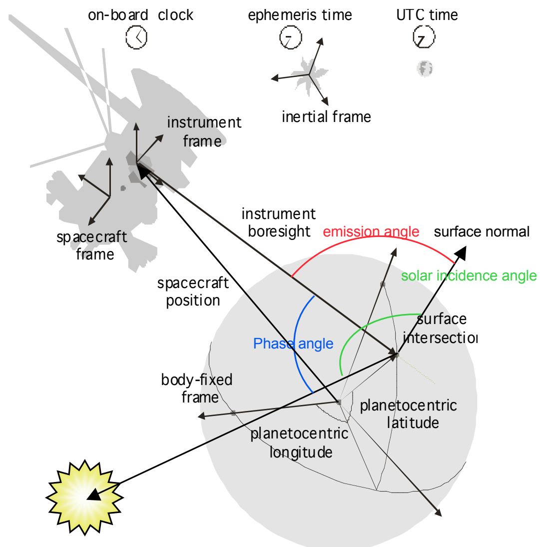
Time transformation kernels

Orientation models

Instrument descriptions

Shapes of satellites, planets

Ephemerides for spacecraft,
Saturn barycenter and satellites.



Which kinds of kernels are needed?

Data required to compute vectors, rotations and other parameters shown in the picture are stored in the SPICE kernels listed below.

Note: these kernels have been selected to support this presentation; they should not be assumed to be appropriate for user applications.

Parameter	Kernel Type	File name
time conversions	generic LSK	naif0008.tls
	CASSINI SCLK	cassini.tsc
satellite orientation	generic PCK	pck00008.tpc
satellite shape	generic PCK	pck00008.tpc
satellite position	planet/sat ephemeris SPK	020514_SE_SAT105.bsp
planet barycenter position	planet SPK	981005_PLTEPH-DE405S.bsp
spacecraft position	spacecraft SPK	tour9201.bsp
spacecraft orientation	spacecraft CK	cas_050215.bc
instrument alignment	CASSINI FK	cas_v37.tf
instrument boresight	Instrument IK	cas_iss_v09.ti

Load kernels

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The easiest and most flexible way to make these kernels available to the program is via cspice_furnsh. For this example we make a setup file (also called a "metakernel" or "furnsh kernel") containing a list of kernels to be loaded:

```
      Note:  these kernels have been selected to support this presentation; they
      should not be assumed to be appropriate for user applications.
\begindata

   KERNELS_TO_LOAD = ( 'naif0008.tls',             'cassini.tsc',
                       'pck00008.tpc',             '020514_SE_SAT105.bsp',
                       '981005_PLTEPH-DE405S.bsp', 'tour9201.bsp',
                       'cas_050215.bc',            'cas_v37.tf',
                       'cas_iss_v09.ti'                                    )
\begintext
```

and we make the program prompt for the name of this setup file:

```
read, setupf, PROMPT='Enter setup file name > '
cspice_furnsh, setupf
```


Programming Solution

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- Prompt for setup file ("metakernel") name; load kernels specified via setup file. (Done on previous chart.)
- Prompt for user inputs required to completely specify problem. Obtain further inputs required by geometry routines via Icy calls.
- Compute the intersection of the boresight direction ray with the surface of the satellite, presented as a triaxial ellipsoid.

  If there is an intersection,

  - Convert Cartesian coordinates of the intersection point to planetocentric latitudinal and planetodetic coordinates
  - Compute spacecraft-to-intercept point range and spacecraft-to-target center range
  - Find the illumination angles (phase, solar incidence, and emission) at the intercept point
- Display the results.

We discuss the geometric portion of the problem first.

Compute surface intercept

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Compute the intercept point (point) of the instrument boresight vector (insite) with the satellite's (satnm) surface at the TDB time of interest (et). This call also returns the distance between the spacecraft and intercept point (dist), the light-time corrected epoch at the intercept point (trgepc), the target center-to-spacecraft vector (obspos), and a boolean flag indicating whether the intercept was found (found).

Note: undefined variables are in red; results are in blue.

```
cspice_srfxpt, 'Ellipsoid', satnm, et, 'CN+S', scnm, iframe, $
               insite, point, dist, trgepc, obspos, found
```

The ranges we want are obtained from the outputs of cspice_srfxpt. These outputs are defined only if a surface intercept is found. If found is true, the spacecraft-to-surface intercept range is the output argument dist, and the spacecraft-to-target center range is the norm of the output argument obspos. Units are km. We use the Icy function cspice_vnorm to obtain the norm:

```
cspice_vnorm( obspos )
```

We'll write out the range data along with the other program results.

Compute Lat/Lon and Illumination Angles

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Compute the planetocentric latitude (pclat) and longitude (pclon), as well as the planetodetic latitude (pdlat) and longitude (pdlon) of the intersection point.

```
if ( found ) then begin

   cspice_reclat, point, r, pclon, pclat

   ;; Let re, rp, and f be the satellite's longer equatorial
   ;; radius, polar radius, and flattening factor.

   re  =  radii[0]
   rp  =  radii[2]
   f   =  ( re - rp ) / re;

   cspice_recgeo, point, re, f, pdlon, pdlat, alt
```

The illumination angles we want are the outputs of cspice_illum. Units are radians.

```
cspice_illum, satnm, et, 'CN+S', scnm, point, phase, solar, emissn
```

Geometry Calculations: Summary

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```
;; Compute the boresight ray intersection with the surface of the
;; target body. `dist' and cspice_vnorm(obspos) yield desired ranges.

cspice_srfxpt, 'Ellipsoid', satnm, et, 'CN+S', scnm, iframe, $
               insite, point, dist, trgepc, obspos, found

;; If an intercept is found, compute planetocentric and planetodetic
;; latitude and longitude of the point.

if ( found ) then begin
   cspice_reclat, point, r, pclon, pclat
   ;; Let re, rp, and f be the satellite's longer equatorial
   ;; radius, polar radius, and flattening factor.
   re  =  radii[0]
   rp  =  radii[2]
   f   =  ( re - rp ) / re;
   cspice_recgeo, point, re, f, pdlon, pdlat, alt

   ;; Compute illumination angles at the surface point.

  cspice_illum, satnm, et, 'CN+S', scnm, point, phase, solar, emissn
  ...
endif else begin
  ...
```


Get inputs - 1

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The code above used quite a few inputs that we don't have yet:

- **TDB epoch of interest (`et`);**
- **satellite and s/c names (`satnm, scnm`);**
- **satellite ellipsoid radii (`radii`);**
- **instrument fixed frame name (`iframe`);**
- **instrument boresight vector in the instrument frame (`insite`);**

Some of these values are user inputs; others can be obtained via CSPICE calls once the required kernels have been loaded.

Let's prompt for the satellite name (`satnm`), spacecraft name (`scnm`), instrument name (`instnm`) and time of interest (`time`):

```
read, satnm , PROMPT='Enter satellite name  > '
read, scnm  , PROMPT='Enter spacecraft name > '
read, instnm, PROMPT='Enter instrument name > '
read, time  , PROMPT='Enter time            > '
```

Get Inputs - 2

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Then we can get the rest of the inputs from CSPICE calls:

To get the TDB epoch (`et`) from the user-supplied time string (which may refer to the UTC, TDB or TT time systems):

```
cspice_str2et, time, et
```

To get the satellite's ellipsoid radii (`radii`):

```
cspice_bodvrd, satnm, "RADII", 3, radii
```

To get the instrument boresight direction (`insite`) and the name of the instrument frame (`iframe`) in which it is defined:

```
cspice_bodn2c, instnm, instid, found
if ( NOT found ) then begin
  print, "Unable to determine ID for instrument: ", instnm
  return
endif
cspice_getfov, instid, ROOM, shape, iframe, insite, bundry
```


Getting inputs: summary

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```
;; Prompt for the user-supplied inputs for our program
read, setupf, PROMPT='Enter setup file name > '
cspice_furnsh, setupf

read, satnm , PROMPT='Enter satellite name  > '
read, scnm  , PROMPT='Enter spacecraft name > '
read, instnm, PROMPT='Enter instrument name > '
read, time  , PROMPT='Enter time            > '

;; Get the epoch corresponding to the input time:
cspice_str2et, time, et
;; Get the radii of the satellite.
cspice_bodvrd, satnm, "RADII", 3, radii
;; Get the instrument boresight and frame name.
cspice_bodn2c, instnm, instid, found
cspice_getfov, instid, ROOM, shape, iframe, insite, bundry
```

Display results


```
;; Display results. Convert angles from radians to degrees for output.
print
print, 'Intercept planetocentric longitude      (deg):  ', $
                                                   cspice_dpr()*pclon
print, 'Intercept planetocentric latitude       (deg):  ', $
                                                   cspice_dpr()*pclat
print, 'Intercept planetodetic longitude        (deg):  ', $
                                                   cspice_dpr()*pdlon
print, 'Intercept planetodetic latitude         (deg):  ', $
                                                   cspice_dpr()*pdlat
print, 'Range from spacecraft to intercept point (km):  ', $
                                                                 dist
print, 'Range from spacecraft to target center   (km):  ', $
                                                 cspice_vnorm(obspos)
print, 'Intercept phase angle                   (deg):  ', $
                                                   cspice_dpr()*phase
print, 'Intercept solar incidence angle         (deg):  ', $
                                                   cspice_dpr()*solar
print, 'Intercept emission angle                (deg):  ', $
                                                  cspice_dpr()*emissn

endif else begin
    print, 'No intercept point found at ' + time
endelse
END
```


Complete the program

To finish up the program we need to declare the variables we've used.

- **We'll highlight techniques used by NAIF programmers**
- **Add remaining IDL code required to make a syntactically valid program**

```
PRO PROG_28

   ABCORR = 'CN+S'
   ROOM   = 10L
   setupf = ''
   satnm  = ''
   scnm   = ''
   instnm = ''
   time   = ''
   R2D    = cspice_dpr()
```

Complete source code -1

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```
;; Prompt for the user-supplied inputs for our program.
read, setupf, PROMPT='Enter setup file name > '
cspice_furnsh, setupf
read, satnm , PROMPT='Enter satellite name  > '
read, scnm  , PROMPT='Enter spacecraft name > '
read, instnm, PROMPT='Enter instrument name > '
read, time  , PROMPT='Enter time            > '

;; Get the epoch corresponding to the input time:
cspice_str2et, time, et

;; Get the radii of the satellite.
cspice_bodvrd, satnm, 'RADII', 3, radii

;; Get the instrument boresight and frame name.

cspice_bodn2c, instnm, instid, found
if ( NOT found ) then begin
   print, "Unable to determine ID for instrument: ", instnm
   return
endif
cspice_getfov, instid, ROOM, shape, iframe, insite, bundry
```


Complete source code -2

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```
;; Compute the boresight ray intersection with the surface of the
;; target body. `dist' and cspice_vnorm(obspos) yield desired ranges.
cspice_srfxpt, 'Ellipsoid', satnm, et, ABCORR, scnm  , iframe, $
                insite, point, dist, trgepc, obspos, found

;; If an intercept is found, compute planetocentric and planetodetic
;; latitude and longitude of the point.
if ( found ) then begin
   cspice_reclat, point, r, pclon, pclat
   ;;Let re, rp, and f be the satellite's longer equatorial
   ;; radius, polar radius, and flattening factor.
   re = radii[0]
   rp = radii[2]
   f  = ( re - rp ) / re
   cspice_recgeo, point, re, f, pdlon, pdlat, alt


   ;; Compute illumination angles at the surface point.
   cspice_illum, satnm, et, ABCORR, scnm, point, phase, solar, emissn

   ;; Display results.  Convert angles from radians to degrees
   ;; for output.
   print
   print, 'Intercept planetocentric longitude      (deg):  ', $
                                                       R2D*pclon
```

Complete source code -4

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```
      print, 'Intercept planetocentric latitude       (deg):  ', $
                                                         R2D*pclat
      print, 'Intercept planetodetic longitude        (deg):  ', $
                                                         R2D*pdlon
      print, 'Intercept planetodetic latitude         (deg):  ', $
                                                         R2D*pdlat
      print, 'Range from spacecraft to intercept point (km):  ', $
                                                              dist
      print, 'Range from spacecraft to target center   (km):  ', $
                                                cspice_vnorm(obspos)
      print, 'Intercept phase angle                   (deg):  ', $
                                                         R2D*phase
      print, 'Intercept solar incidence angle         (deg):  ', $
                                                         R2D*solar
      print, 'Intercept emission angle                (deg):  ', $
                                                        R2D*emissn

   endif else begin
      print, 'No intercept point found at ' + time
   endelse

   ;; Police-up active IDL memory, unload the kernels.
   cspice_unload, setupf
END
```


Compile the program

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Though IDL functions in a manner similar to interpreted languages, it does compile source files to a binary form.

First, ensure that both the Icy Toolkit, and an IDL installation are properly installed. IDL must load the Icy DLM, icy.dlm/icy.so(dll) to compile those scripts containing Icy calls. IDL loads DLMs from default locations and from the current directory when the user ran IDL. The user may also explicitly load a DLM with the `dlm_register` **command.**

Now compile the code.

Compile and link the program - 2

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Terminal Window

```
IDL>  .compile prog_28.pro
% Compiled module: PROG_28.
```


Running the program

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It looks like we have everything taken care of:

- **We have all necessary kernels**
- **We made a setup file (metakernel) pointing to them**
- **We wrote the program**
- **We compiled the program**

Let's run it.

Running the program

Terminal Window

```
IDL>   prog_28
Enter setup file name > setup.ker
Enter satellite name  > titan
Enter spacecraft name > cassini
Enter instrument name > cassini_iss_nac
Enter time            > 2005 feb 15 8:15 UTC

Intercept planetocentric longitude      (deg):     -156.44300
Intercept planetocentric latitude       (deg):      18.788539
Intercept planetodetic longitude        (deg):     -156.44300
Intercept planetodetic latitude         (deg):      18.788539
Range from spacecraft to intercept point (km):      4810.9419
Range from spacecraft to target center   (km):      7384.3266
Intercept phase angle                   (deg):      43.274593
Intercept solar incidence angle         (deg):      41.038429
Intercept emission angle                (deg):      2.5146132
```