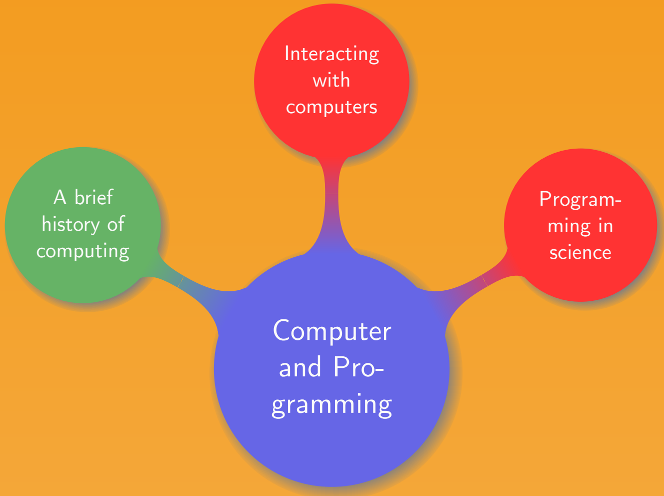
Introduction to Computer and Programming

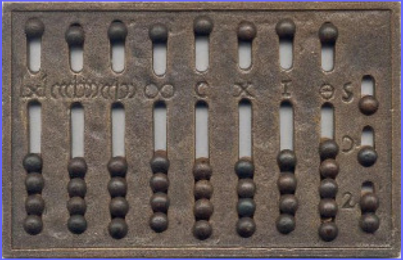
1. Computer and Programming

Manuel – Summer 2019

Chapter organisation



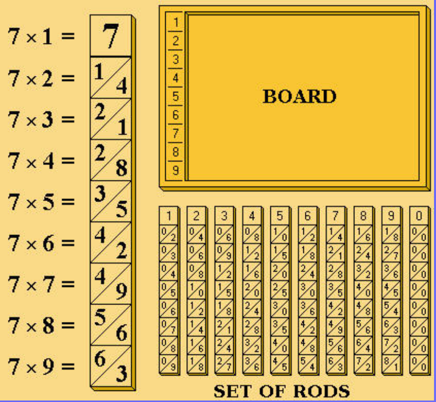
Ancient era



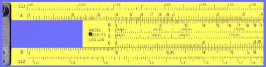
Abacus (-2700)

Antikythera mechanism (-100)

Calculation tools

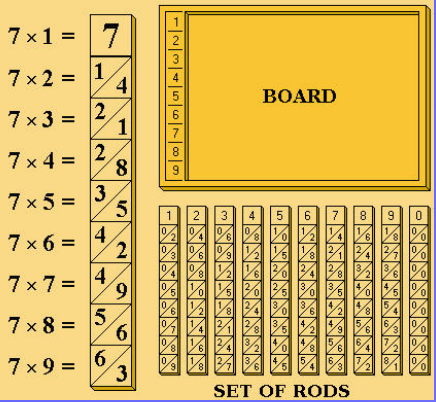


Napier's bones (1617)



Sliderule (1620)

Calculation tools



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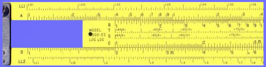
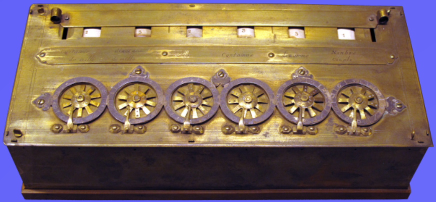


Sliderule (1620)

First pocket calculator introduced around 1970 in Japan

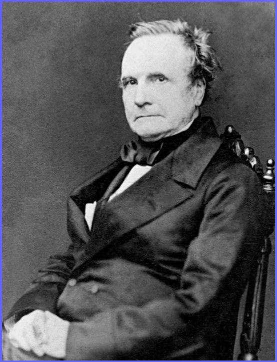
Mechanical calculators



Pascaline (1642)

Arithmomètre (1820)

The 19th century



Charles Babbage (1791–1871) achievements:

- Difference engine: built in the 1990es
- Analytical engine: never built

Ada Byron (1815–1852) achievements:

- Extensive notes on Babbage's engines
- Algorithm to calculate Bernoulli numbers

The birth of modern computing

First part of the 20th century:

- 1936: First freely programmable computer
- 1946: First electronic general-purpose computer

- 1936: First freely programmable computer
- 1948: Invention of the transistor
- 1951: First commercial computer
- 1958: Integrated circuit

UNIVAC I (1951)

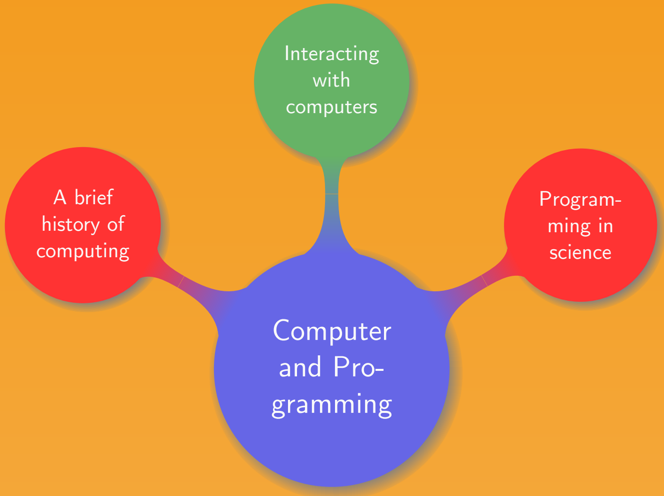
Modern computing

Apple I (1976)

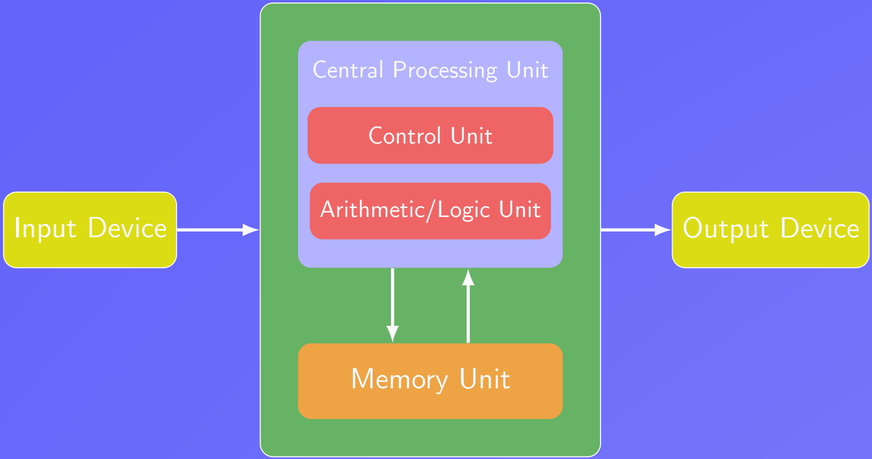
Second part of the 20th century:

- 1962: First computer game
- 1969: ARPAnet
- 1971: First microprocessor
- 1975: First consumer computers
- 1981: First PC, MS-DOS
- 1983: First home computer with a GUI
- 1985: Microsoft Windows
- 1991: Linux

Chapter organisation



Von Neumann architecture



What does a computer understand?

Numbers in various bases:

- Humans use *decimal* (0, 1, 2, 3, 4, 5, 6, 7, 8, 9), e.g. $(253)_{10}$
- Computers work internally using *binary* (0,1), e.g $(11111101)_2$
- Human-friendly way to represent binary: *hexadecimal* (0,1,2,3,4,5,6,7,8,9,A,B,C,D,E,F), e.g. $(FD)_{16}$

Number base conversion

Base conversion:

- From base b into decimal: evaluate the polynomial
  $(11111101)_2 = 1 \cdot 2^7 + 1 \cdot 2^6 + 1 \cdot 2^5 + 1 \cdot 2^4 + 1 \cdot 2^3 + 1 \cdot 2^2 + 0 \cdot 2^1 + 1 \cdot 2^0 = 253$

  $(\mathrm{FD})_{16} = \mathrm{F} \cdot 16^1 + \mathrm{D} \cdot 16^0 = 15 \cdot 16^1 + 13 \cdot 16^0 = 253$

- From decimal into base b: repeatedly divide n by b until the quotient is 0. Consider the remainders from right to left
  rem(253,2)=1, rem(126,2)=0, rem(63,2)=1, rem(31,2)=1, rem(15,2)=1, rem(7,2)=1, rem(3,2)=1, rem(1,2)=1

  rem(253,16)=13=D, rem(15,16)=15=F

- From base b into base b^a: group numbers into chunks of a elements

  $(11111101)_2 = 1111\ 1101 = (\mathrm{FD})_{16}$

Quick examples

Exercise.

- Convert into hexadecimal: 1675, 321, $(100011)_2$, $(10111011)_2$
- Convert into binary: 654, 2049, ACE, 5F3EC6
- Convert into decimal: $(111110)_2$, $(10101)_2$, $(12345)_{16}$, 12C3C

Quick examples

Exercise.

- Convert into hexadecimal: 1675, 321, $(100011)_2$, $(10111011)_2$
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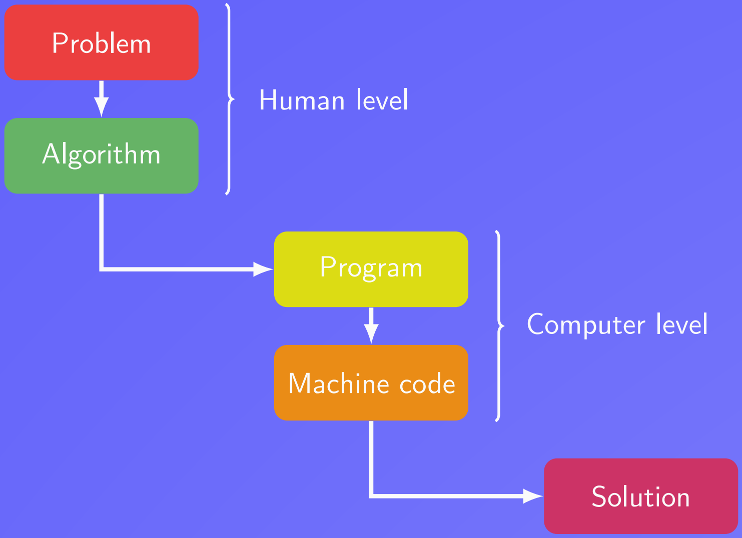
- Convert into decimal: $(111110)_2$, $(10101)_2$, $(12345)_{16}$, 12C3C

Solution.

- $1675 = (68B)_{16}$, $321 = (141)_{16}$, $(100011)_2 = (23)_{16}$
- $654 = 1010001110$, $2049 = 100000000001$,
  $\mathrm{ACE} = 101011001110$, $\mathrm{5F3EC6} = 10111110011111011000110$
- $(111110)_2 = 62$, $(10101)_2 = 21$, $(12345)_{16} = 74565$,
  $\mathrm{12C3C} = 76860$

How to use a computer?



Algorithm

Algorithm: recipe explaining the computer how to solve a problem

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Example.
Detail an algorithm to prepare a jam sandwich.

Actions: `cut`, `listen`, `spread`, `sleep`, `take`, `eat`, `dip`, `assemble`
Things: `knife`, `guitar`, `bread`, `honey`, `jam jar`, `sword`, `slice`

Algorithm

Algorithm: recipe explaining the computer how to solve a problem

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Detail an algorithm to prepare a jam sandwich.

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Things: `knife`, `guitar`, `bread`, `honey`, `jam jar`, `sword`, `slice`

Algorithm. (*Sandwich making*)

Input : 1 bread, 1 jam jar, 1 knife
Output: 1 jam sandwich

take the knife and cut 2 slices of bread;
dip the knife into the jam jar;
spread the jam on the bread, using the knife;
assemble the 2 slices together, jam on the inside;

Humans and computers

From algorithm to machine code

Algorithm → Programming language

↓

Machine code ← Interpreter or compiler

A first program

Example.

Given a square and the length of one side, what is its area?

Algorithm.

Input : side (the length of one side of a square)

Output: the area of the square

return side $\times$ side

A first program

Example.
Given a square and the length of one side, what is its area?

Algorithm.

Input : side (the length of one side of a square)
Output: the area of the square
return side $\times$ side

To obtain the result in MATLAB:

1. Type the code
2. Press `Enter`

area.m

```
a=input("Side: ");
printf ("Area: %d",  a*a)
```

Running the program

area.c

```c
#include<stdio.h>
int main() {
  int side;
  printf("Side: ");
  scanf("%d",&side);
  printf("Area: %d", side*side);
  retrun 0;
}
```

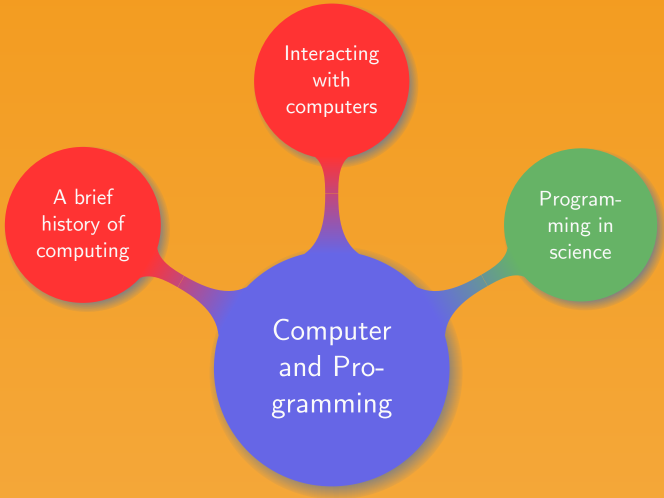
area.cpp

```cpp
#include <iostream>
using namespace std;
int main() {
int side;
  cout << "Side: ";  cin >> side;
  cout << "Area: " << side*side;
  return 0;
}
```

To obtain the result in C or C++

1. Write the source code
2. Compile the program
3. Run the program

Chapter organisation



MATLAB

Common mathematics software:

- Axiom
- GAP
- GP/PARI
- Magma
- Maple
- MATLAB
- Maxima
- Octave
- R
- Scilab
- Mathematica

[1]Studied in VG101

MATLAB

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MATrix LABoratory (MATLAB):

- Matrix manipulations[1]
- Implement algorithms[1]
- Plotting functions and data[1]
- User interface creation

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MATLAB

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MATrix LABoratory (MATLAB):

- Matrix manipulations[1]
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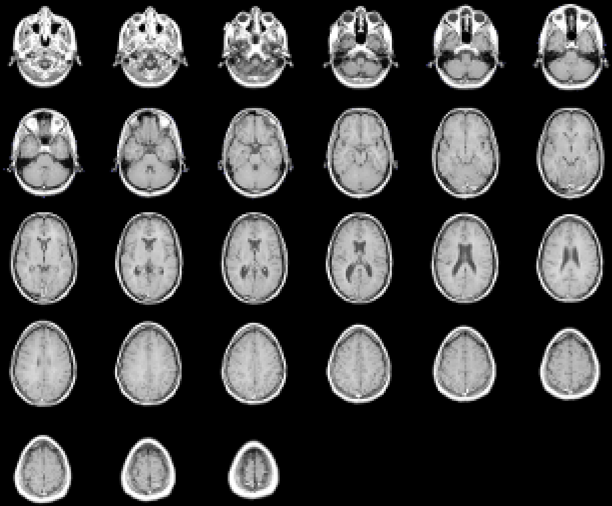
- Plotting functions and data[1]
- User interface creation

Benefits of MATLAB:

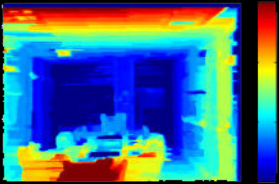
- Easy to use
- Built-in language
- Versatile
- Many toolboxes

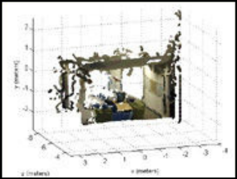
[1] Studied in VG101

MRI slices

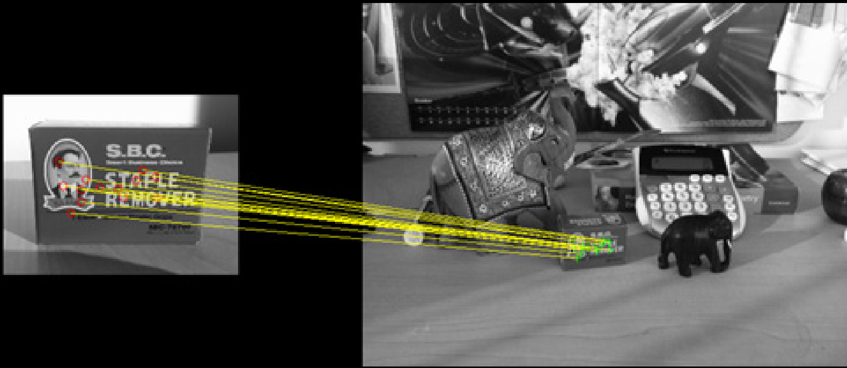


Stereo Vision





Object detection



Mathematics and Physics

$$\begin{tikzcd}
\text{Physics problem} \arrow[r] & \text{Mathematics problem} \arrow[d] \\
& \text{Mathematical solution}
\end{tikzcd}$$

Mathematics and Physics

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\begin{tikzcd}
\text{Physics problem} \arrow[r] & \text{Mathematics problem} \arrow[d] \\
\text{Physical solution} & \text{Mathematical solution} \arrow[l]
\end{tikzcd}
$$

Mathematics and Physics

$$\begin{tikzcd}
\text{Physics problem} \arrow[r] & \text{Mathematics problem} \arrow[d] \\
\text{Physical solution} \arrow[u] & \text{Mathematical solution} \arrow[l]
\end{tikzcd}$$

What to do?

Before jumping on the computer and starting to code:

- Clearly state or translate the problem
- Define what is known as the *input*
- Define what is to be found as the *output*
- Develop an *algorithm*, i.e. a systematic way to solve the problem
- Verify the solution on simple input
- Implementing the algorithm

Solving a problem using a computer

Example.
Given that the sun is located $1.496 \cdot 10^8$ km away from the Earth and has a circumference of $4.379 \cdot 10^6$ km, calculate its density.

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Strategy to solve the problem:

- Easy part
  - Problem: finding the density of the sun
  - Input: distance r, circumference c
  - Output: density d

Solving a problem using a computer

Example.
Given that the sun is located $1.496 \cdot 10^8$ km away from the Earth and has a circumference of $4.379 \cdot 10^6$ km, calculate its density.

Strategy to solve the problem:

- Easy part
  - Problem: finding the density of the sun
  - Input: distance r, circumference c
  - Output: density d
- Finding the density is slightly more complicated:
  1. Approximate the Sun by a sphere and determine its volume V
  2. Think of Kepler's third law $\frac{T^2}{r^3} = \frac{4\pi^2}{GM}$
  3. Apply Kepler's third law to find the mass $M = \frac{4\pi^2 r^3}{GT^2}$

The Algorithm

Algorithm. (*Desnity of the Sun*)

Input : $r = 1.496 \cdot 10^8,\ c = 4.379 \cdot 10^6,\ G = 6.674 \cdot 10^{-11},$
$T = 365$

Output: Density of the Sun

$V \leftarrow \frac{4}{3}\pi(\frac{c}{2\pi})^3$;
$M \leftarrow \frac{4\pi^2 r^3}{GT^2}$;
return $\frac{M}{V}$;

The Algorithm

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Input : $r = 1.496 \cdot 10^8,\ c = 4.379 \cdot 10^6,\ G = 6.674 \cdot 10^{-11},$
$T = 365$

Output: Density of the Sun

1 $V \leftarrow \frac{4}{3}\pi(\frac{c}{2\pi})^3$;

2 $M \leftarrow \frac{4\pi^2 r^3}{GT^2}$;

3 **return** $\frac{M}{V}$;

After running the algorithm we find 338110866080

WRONG!

WRONG!

Units are not consistent...

The Algorithm

Algorithm. (*Density of the Sun*)

Input : $r = 1.496 \cdot 10^{11}$ m, $c = 4.379 \cdot 10^{9}$ m, $T = 365 * 24 * 3600$ s, $G = 6.674 \cdot 10^{-11}$ m^3/kg/s^2

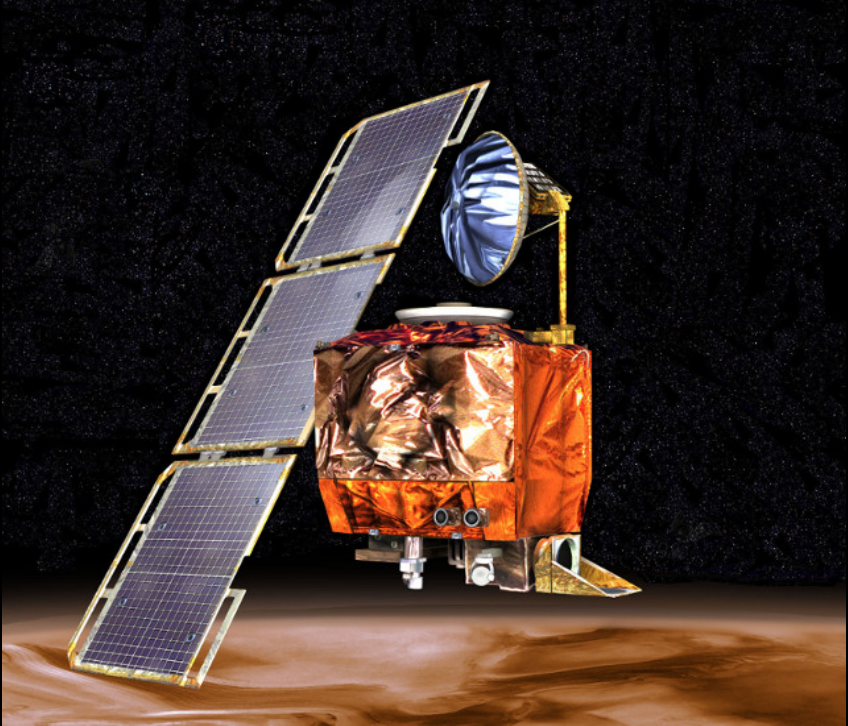
Output: Density of the Sun

$V \leftarrow \frac{4}{3}\pi(\frac{c}{2\pi})^3$;

$M \leftarrow \frac{4\pi^2 r^3}{GT^2}$;

return $\frac{M}{V}$;

After running the algorithm we find 1404 kg/m^3



Key points

- What is a programming language?
- What are the two main types of programming language?
- What is an algorithm?
- How to tackle a problem?

Thank you!

References I

1.3 https://upload.wikimedia.org/wikipedia/commons/b/b5/RomanAbacusRecon.jpg

1.3 https://upload.wikimedia.org/wikipedia/commons/7/76/Antikythera_model_front_panel_Mogi_Vicentini_2007.JPG

1.4 https://upload.wikimedia.org/wikipedia/commons/5/54/Batons_de_Napier.png

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1.6 https://upload.wikimedia.org/wikipedia/commons/6/6b/Charles_Babbage_-_1860.jpg

1.6 https://upload.wikimedia.org/wikipedia/commons/b/b1/Ada_Byron_aged_seventeen_%281832%29.jpg

1.7 http://www.cftea.com/c/2011/02/WPRMMSW80E5HFKI7/97GZAM05GBMCV7P9.jpg

1.8 https://upload.wikimedia.org/wikipedia/commons/a/a1/Apple_I_Computer.jpg

1.21 MATLAB documentation

1.22 MATLAB documentation

1.23 MATLAB documentation

References II

1.30 https://upload.wikimedia.org/wikipedia/commons/thumb/1/19/Mars_Climate_Orbiter_2.jpg/660px-Mars_Climate_Orbiter_2.jpg